PETROLEUM REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

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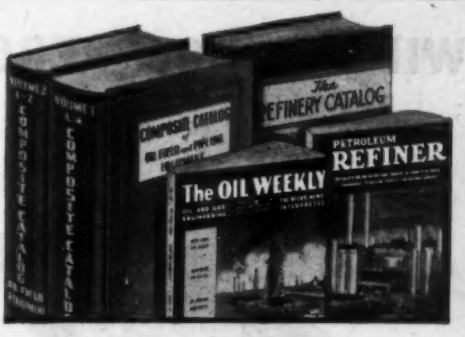

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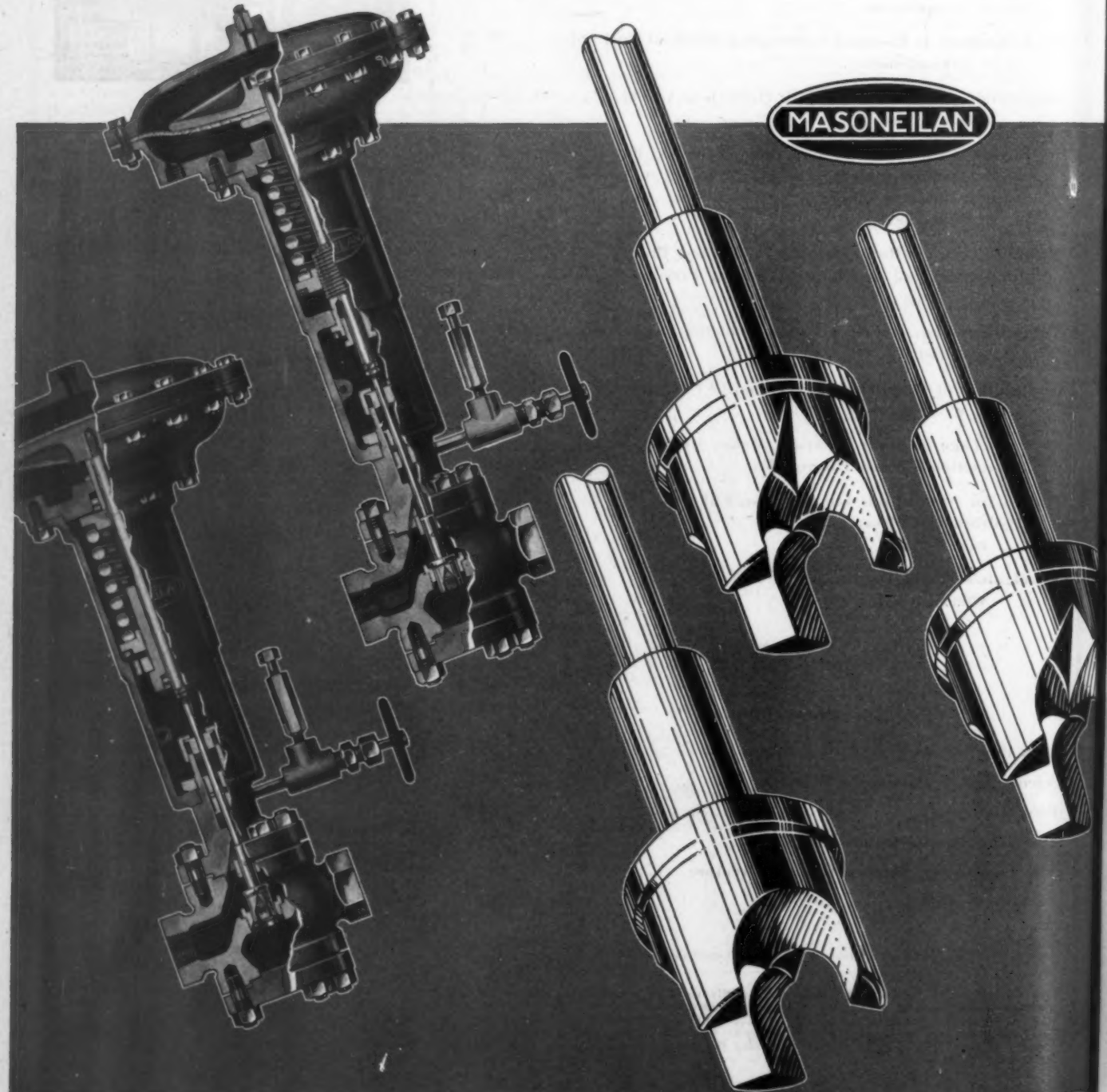

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THE LOOK BOX

Secondary Matter

ONE of the errors of this day is the hope that denial to one man assures something for others. By taxation, one man is denied his $100,000 per year and the sponsors of that program would have 99 other men believe that each will receive $1,000 in income per year.

Results are to the contrary, but the 99 get some sort of satisfaction out of the assurance that the one man no longer gets his fantastic hundred grand.

There is similar reasoning in the program of restricting ownership of patents. Politicians point out that it is unfair for one man to hold so many patents, or even to own patents. By inference they would have others believe that benefits from patents will become widespread, once the few are denied ownership.

Falsity of the reasoning does not detract for popularity of what is promised.

Recently this nation lost through death Thomas Midgley, Jr., who owned several patents. The refining industry is familiar with his tetra-ethyl lead discovery. Can any one believe that halting Midgley with one discovery would have assured that some other individual would produce Freon?

Halting him more likely would have meant that Freon, the refrigerant, was not even available when it became so useful as a killer of insects in the jungles of the Pacific islands.

No nation can have plenty unless it produces in that fashion. Income, wealth and patent ownership are secondary considerations.

Little Short Of Disgrace

IT IS little short of disgraceful that shortages of ingredients continue to hamper output of finished rubber products. Such, however, is the condition that has made it necessary for the government to demand the services of John L. Collyer as rubber director.

Three years ago the findings of the Baruch Committee revealed conditions that defied explanation. By bold tactics William M. Jeffers made exceptional progress in plant construction and Bradley Dewey followed with excellent results in getting output of butadiene and styrene up to required tonnage.

One after the other the two men left their posts and the public had reason to believe that the problem of rubber had been overcome, despite the confusion that followed Pearl Harbor.

Now it develops that other materials, especially carbon black and rayon, are not sufficient to permit making the casings and other products essential to the military effort. Meanwhile the tires in civilian use come closer to disintegration.

Somewhere the estimates of those in authority in Washington failed to match actual requirements. Capacity for carbon black and rayon could have been provided while plants for butadiene, styrene and copolymerization were being built. Men in authority did not know or did not care.

The situation in rubber is another instance in proof of the contention that a planned economy cannot provide required quantity.

It is to be hoped that Director Collyer meets no

F A M O U S

Caustic Comments

In the course of conversation at a cocktail party, a tactless woman remarked to the late Alexander Woollcott, "I don't like you . . . I simply cannot bear nitwits."

"You are not at all like your mother, are you?" was Woollcott's caustic rejoinder.

Dow

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interference. His record of getting things done indicates that he will correct this matter if left to pursue methods of his choosing.

Gasoline Situation

IT IS comforting to study some figures which reveal that the amount of gasoline, both military and civilian, in storage in the United States had continued to rise while the military campaigns of Europe and the Pacific rose in their intensity. This accomplishment is not spectacular but it does make one wonder why so many news releases from Washington are built on the theme that petroleum products are barely sufficient for military use.

Along the Gulf Coast military and civilian gasoline stocks in early April were around 16,500,000 barrels, a figure in line with expectation and in line with the totals of 1942, when total storage ranged from a low of 14,000,000 and a high of 19,500,000 barrels. Since this area can comfortably carry a storage total of 20,000,000 barrels, its refining plants can continue to build a reserve in this country against military needs.

With the fall of Germany it is certain that military gasoline consumption will recede. This lull is not expected to result in serious change in plant operating schedules. Recently General Arnold said that the intensity of air warfare against Japan would be stepped up by as much as cessation in Europe will permit. Under such a program some gasoline can go into storage while men and equipment are moving from one theatre to another.

In this development it is likely that there will be material addition to motor fuel of grade for civilian use. Some students of the trend are convinced that it will be advisable to increase gallonage on A-card distribution in the rationing program.

Bargaining Pioneer

THIS estimate of the work of Clarence J. Hicks was part of article concerning his life in a recent issue of "The Lamp." As a trustee Industrial Relations Counsellors, Inc., and his activity with Standard Oil Company (New Jersey) gave him opportunity for shaping much of the progress in the relationships of the men and women who work in industry.

"His greatest single contribution was his creation of what he called industrial representation. He was impatient with arbitrary decisions made by top executives and handed to employes without adequate explanation of the thinking back of the orders. He believed there was essentially no difference between the human motives of the man who worked with a pick and shovel and those of a corporation president. When strikes broke out he thought the blame too often belonged to the employer who had failed to understand employe grievances. Since obviously the executives could not personally consult thousands of workers, Mr. Hicks proposed the election of employe representatives to act as spokesmen in policy decisions. Through his efforts collective bargaining was conceived and put into effect before the phrase became a part of the language."

Joy on Paper

WHEN the Office of Defense Transportation classed conventions as a non-essential, the move met approval. Even the most ardent convention addict could not defend these gatherings as possessing full-scale usefulness. Compared with transporting men and supplies for military purposes, the man going to a convention is simply excess baggage.

But ODT has followed that wise move by issuing a brochure, by which it reveals the delightful flight into fancy of "holding a convention by mail." Imagine the pleasure of looking forward to receipt of an elaborate convention program, then the printed opening remarks of the president of some essential association, with the continued receipt of two speeches per week for 10 weeks, after which all the speeches are bound in one volume and mailed to each man so unfortunate as to have to stay at home when he would prefer going to a convention.

And, to start the whole assortment of arriving at so thrilling an accomplishment, ODT suggests that the man take his wife out to dinner. Somewhere in it cigarettes were mentioned.

All the while there is a shortage of paper.

High Wages Low Prices

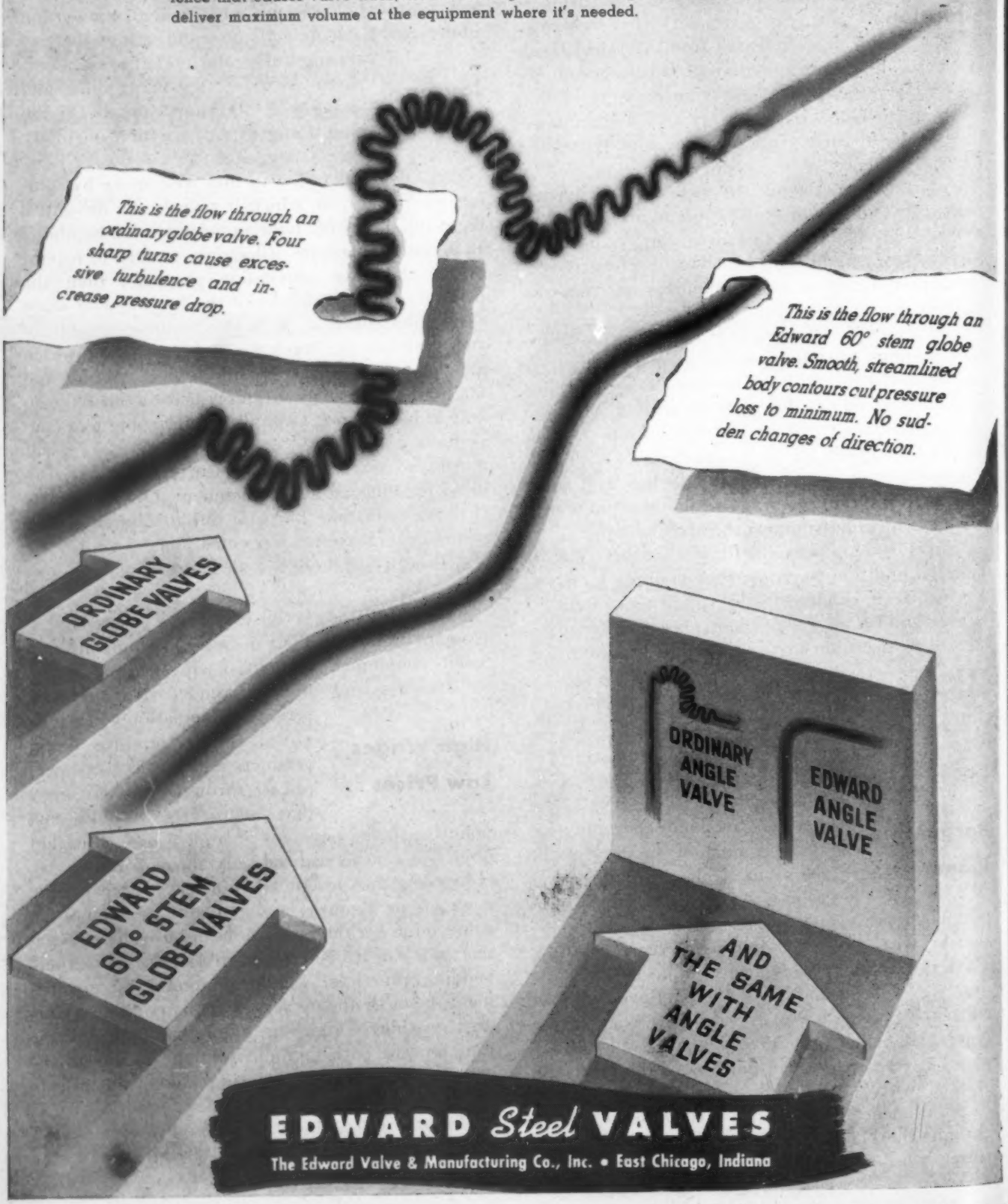
THIS function of business was stated by J. Howard Pew, president of Sun Oil Company, before a conference of business-paper editors:

"Business and industry render their greatest service to the nation when they consistently produce better products and services at lower prices through an efficiency that reconciles a low-cost policy with the payment of high wages. But that objective can be realized only through constantly increasing the productive efficiency of everyone engaged in business and industry. It cannot be achieved under the restrictions of bureaucratic control; nor can it be achieved in the face of featherbedding practices, whether imposed by government, labor or the owners of industry; and it cannot be achieved if we are going to adopt policies that remove both stimulus and the means to increased efficiency by reducing alike the rewards for seeking it and the penalties for ignoring it."

Maintaining competition is in his opinion the best assurance of more and better things, at lower prices, with increasing wages.

Here's how Edward Valves cut waste and end costly pressure loss . . .

Pressure drop is a fuel thief. Pressure loss through your small globe and angle valves can be reduced greatly by standardizing on Edward forged steel valves. Compare these flow lines to see how streamlined Edward forged steel valves prevent the excessive turbulence that causes valve wear, let flow through with no sharp and sudden changes, and deliver maximum volume at the equipment where it's needed.


This is the flow through an ordinary globe valve. Four sharp turns cause excessive turbulence and increase pressure drop.
This is the flow through an Edward 60° stem globe valve. Smooth, streamlined body contours cut pressure loss to minimum. No sudden changes of direction.
ORDINARY GLOBE VALVES
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Heat Content of Petroleum Fractions

D. N. HANSON and C. O. HURD
Shell Devolpment Company, San Francisco

A CHART is presented showing the heat contents in Btu/lb for temperatures from 0° to 1200° F., for liquid and vaporized petroleum fractions. This chart involves °API (10 to 80), UOP characterization factor (10 to 12) and pressure (0 to 1000 psia) as parameters in a manner such that consistency with the correlations of Watson is obtained. Knowledge of the pseudocritical properties for the determination of high pressure vapor heat contents is not required.

HEAT contents of petroleum fractions are among the most frequently required values for engineering calculations. Several convenient tabulations of petroleum heat content are available, such as those of Cragoe[1] and Gould,[3] but unfortunately they are reliable only for specific types of fractions. There is frequent need for heat contents of petroleum fractions which are more aromatic, more olefinic, or more naphthenic than the fractions used as a basis for such tabulations.

The correlations of Watson and co-workers[4, 5, 6, 7] are widely used as the basis for reliable heat contents of petroleum fractions, regardless of their aromatic, olefinic or naphthenic character. For the calculation of a single value these correlations are quite tedious to use, especially for vapors above atmospheric pressures where pseudocritical temperatures and pressures are involved in evaluating the effect of pressure on heat contents.

The use of Watson's correlations has been greatly simplified by the development of charts, Figure 1'* which give liquid and vapor heat contents of petroleum fractions directly in terms of temperature, characterization factor, API gravity and pressure, without the necessity of first calculating specific heats, latent heats, pseudocritical temperature and pressure, and pseudoreduced temperature and pressure. The basis of development follows.

Basis of Development

Petroleum fractions may be readily characterized, i.e., their physical properties may be correlated, by use of the UOP characterization factor developed by Watson and Nelson[4] together with some property such as API gravity. The UOP characterization factor is defined as:

$$K = \frac{\sqrt[3]{\text{Molal average boiling point at one atm., °R}}}{\text{specific gravity, 60° F./60° F.}}$$

where K = UOP characterization factor, and the molal average boiling point is empirically determined from the Engler distillation curve. K may also be approximated from physical properties other than the Engler distillation curve and the density,[8] but these properties are those most generally available for petroleum fractions.

Specific Heats

The specific heats of petroleum liquids at saturation pressure and of petroleum vapors at one atmosphere pressure have been expressed as functions of K and API gravity by Watson and Nelson.[4] Gaucher[2] reviewed the available data and found these correlations to be the most satisfactory available.

Liquid heat contents based on 0° F. were calculated from these equations and were plotted for fractions for which K = 12. For liquids having values of K other than 12, heat contents may be calculated by multiplying these values by a correction factor as given on the small accompanying chart. The heat content lines for any given API gravity were terminated at the highest value of the critical temperature as determined from a correlation by Watson and Nelson.[4]

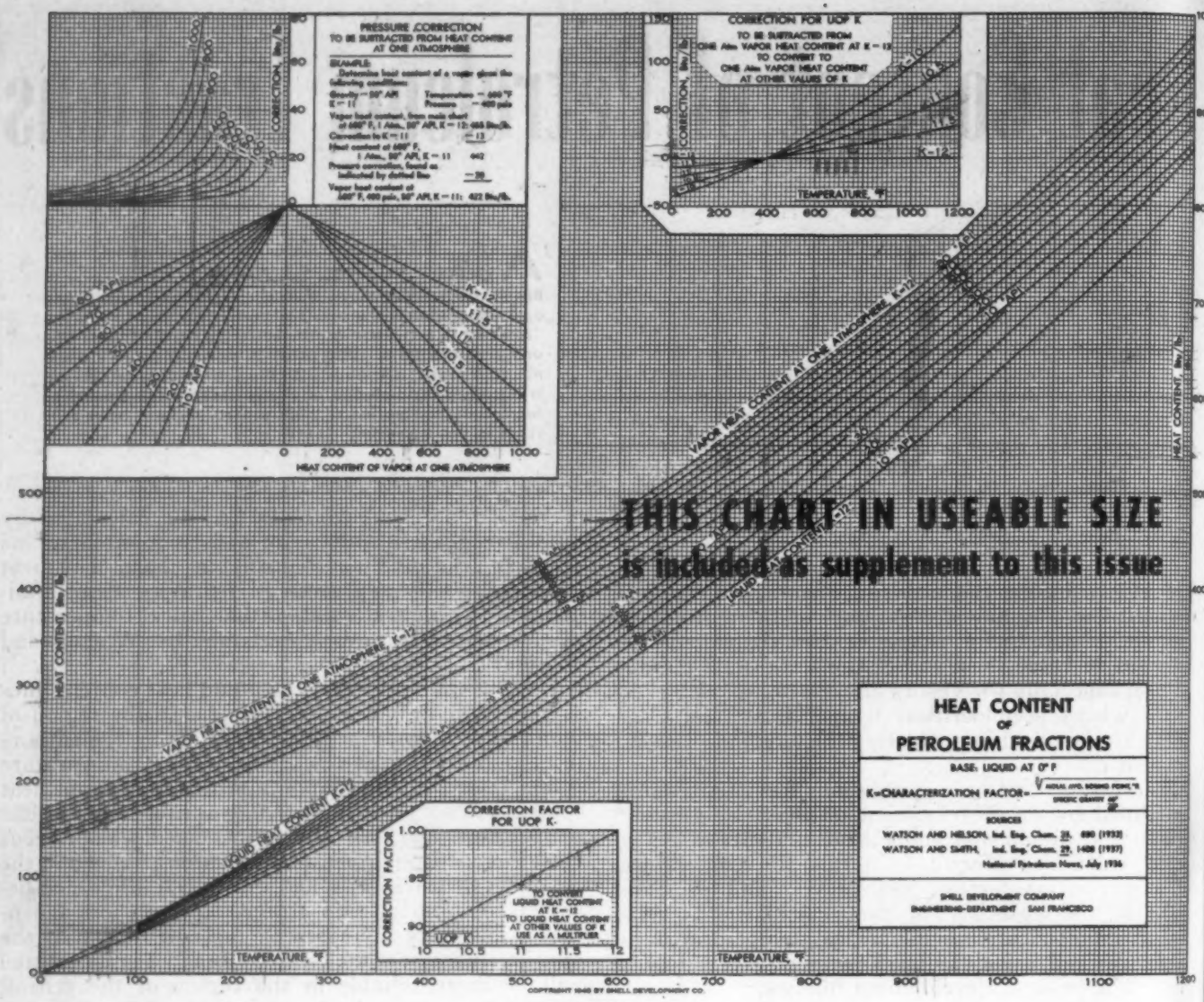
It should be noted that the liquid heat content lines as plotted show no marked increase in the region of the critical temperature. It is believed by the authors that such an increase near the critical temperature would be false. For simple mixtures, the liquid heat content curves proceed smoothly through the critical temperature, and this marked increase does not occur until the critical temperature has been passed and the cricondentherm approached. Since the difference between the critical temperature and the cricondentherm generally increases as the complexity of the mixture increases, the heat content lines as plotted will be more reliable in the region of the critical temperature for complex mixtures than for pure compounds.

Vapor Heat Contents at One Atmosphere

Latent heats of vaporization were obtained from a chart developed by Watson and Nelson.[4] Latent heat of vaporization as defined by Watson and Nelson is equal to the difference between the heat contents of the saturated liquid at one atmosphere and the saturated vapor of the same composition at the same temperature. This assumes that vaporization takes place entirely at the molal average boiling point. Since this concept was used to determine the position of the one atmosphere vapor heat content lines, it should be noted that the points determined were not at one atmosphere, but are at some lower pressure at which the heat contents are essentially those at one atmosphere.

The heat contents of the vapor at one atmosphere and the molal average boiling point were determined by adding the heat content of the liquid at the molal average boiling point and the latent heat of vaporization at the molal average boiling point. Vapor heat content lines at one atmosphere were then established by integration of the heat capacity equation proposed by Watson and Nelson using the values of the heat content at the molal average boiling point to fix the integration constant. Heat content lines for fractions with K = 12 were plotted. A chart to convert to

*HEAT CONTENT OF PETROLEUM FRACTIONS, printed in usable size, and inserted as a supplement to this issue.


PRESSURE CORRECTION
TO BE SUBTRACTED FROM HEAT CONTENT AT ONE ATMOSPHERE
CORRECTION FOR UOP K
TO BE SUBTRACTED FROM ONE Atm VAPOR HEAT CONTENT AT K = 12
TO CONVERT TO ONE Atm VAPOR HEAT CONTENT AT OTHER VALUES OF K
HEAT CONTENT OF VAPOR AT ONE ATMOSPHERE
VAPOR HEAT CONTENT AT ONE ATMOSPHERE, K=12
LIQUID HEAT CONTENT (LCP)
CORRECTION FACTOR FOR UOP K
TO CONVERT LIQUID HEAT CONTENT AT K = 12 TO LIQUID HEAT CONTENT AT OTHER VALUES OF K USE AS A MULTIPLIER
UOP K
CORRECTION FACTOR
HEAT CONTENT, Btu/lb
TEMPERATURE, °F
HEAT CONTENT OF PETROLEUM FRACTIONS
BASE: LIQUID AT 0° F
K=CHARACTERIZATION FACTOR=
SOURCES
WATSON AND NELSON, Ind. Eng. Chem. 25, 880 (1933)
WATSON AND SMITH, Ind. Eng. Chem. 29, 1408 (1937)
National Petroleum News, July 1936
SHELL DEVELOPMENT COMPANY
ENGINEERING DEPARTMENT SAN FRANCISCO
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THIS CHART IN USEABLE SIZE is included as supplement to this issue

FIGURE 1

vapor heat contents for other values of K by use of a subtractive correction was also developed. This correction includes differences both in vapor heat capacity and in heat of vaporization and makes allowance for the change of boiling point with changing K at constant API gravity.

Pressure Correction to Vapor Heat Contents

A pressure correction chart was constructed by calculating values of the correction over the ranges of pressure, temperature, °API, and K shown on the chart and plotting these in various ways until a correlation was found. The chart presented was found to be the most satisfactory from the standpoints of accuracy and ease of reading.

These corrections were determined by means of the concept of pseudocritical properties. Pseudocritical pressures and pseudocritical temperatures were obtained from charts published by Watson and Smith[7] in which these pseudocritical properties are related to the true molal average boiling points rather than to the molal average boiling points. Watson and Smith[7] have defined these average boiling points and established the relationship between them in terms of the slope of the Engler distillation curve. However, since it was impossible to use this relationship in the above development, and since the difference between the two temperatures is small, they were assumed to be equal. This assumption introduces insignificant errors in the values of the pressure correction terms. In the region of the pseudocritical state it produces a maximum error of only 10 percent of the pressure correction.

Values of the pressure correction to the heat content were obtained from a modification of a chart published by Watson and Smith.[6]

Accuracy

Since Figure 1 was developed directly from the correlations of Watson et al and follows these correlations closely, the accuracy of the chart is the same as the accuracy of the original correlations, which are widely accepted as the most satisfactory available. The chart is not recommended in the critical region.

ACKNOWLEDGEMENT

The authors desire to thank Shell Development Company for permission to publish this paper.

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Fuels for High-Speed Diesel Engines

V. A. KALICHEVSKY
Magnolia Petroleum Company, Beaumont, Texas

THE original development of trucks and busses as an important transportation factor was based on use of gasoline engines to supply motive power. This source of power has continued predominant largely because availability of gasoline, increased through technological development, has kept pace with demand.

However, a considerable amount of work has been carried out, leading towards development of diesel engines on the basic presumption that they are less discriminating with respect to fuels. The progress was particularly rapid in Europe where shortage of petroleum is acute. As a result the light-weight high-speed diesel engine was brought into existence and found applications not only for moving road vehicles but even for airplane service.

Meanwhile some large fleet owners began experimenting with the use of kerosine in trucks in long-distance travel. When used in low-compression gasoline engines, kerosine was found to be a satisfactory fuel, provided the engine was hot. The problem was solved by equipping trucks with two fuel tanks. Substitution of diesel for gasoline engines simplified these operating problems and was promising economically because of lower fuel consumption and the use of cheap fuels.[4]

Because of the type of service to which trucks and busses are subjected on public highways it was necessary to use high-speed diesels which are considerably more susceptible to fuel quality than the stationary low-speed engines.

High-speed diesel engines operating at above 1500 r.p.m. are employed in trucks and busses for cross-country and urban service. Medium speed engines operating between 500 and 1500 r.p.m. are used in tractors, power shovels, locomotives, marine power generators, pumps and industrial units when extreme load flexibility is required. Slow-speed diesel engines operating below 500 r.p.m.[6] find application in very large stationary power units and marine installations.

The basic difference in the combustion mechanism of diesel and gasoline engines arises from the method employed for introducing fuel into the cylinders.[7, 25] In gasoline engines fuel is mixed with air before it is injected into the combustion space where it is ignited with an electric spark. In true-diesel engines fuel is injected into cylinders containing compressed air and ignited by heat developed during compression.

Some engines are classified as diesels although they are of intermediate type. For instance, the fuel may be mixed with air before it is admitted to the cylinders (Lanova type combustion chamber) or the fuel may be ignited by electric spark (Hesselman engine) and not by heat of compression. Fuels required by these engines are, therefore, also of intermediate type with respect to certain of their properties.

The two basic injection methods require different fuels for insuring satisfactory engine performance. In gasoline engines the spread of combustion wave should be gradual as otherwise the whole mixture may react instantaneously, causing a violent explo-

TABLE 1

Requirements from Gasoline and High-Speed-Diesel-Engine Fuels

REQUIREMENT	Gasoline	Diesel Fuel
Ignition quality (starting and smooth burning)	Important	Important
Ease of vaporization (or atomization)	Important	Important
Carbonizing tendency (or gum)	Important	Important
Fluidity (viscosity and pour)	Seldom a problem	Important
Cleanliness (freedom from water and deposits)	Important	Important
Stability	Important	Important
Noncorrosiveness	Important	Important
Lubricating properties	Not required	Important
Absence of smoke and odor	Seldom a problem	Important
Fuel economy	Important	Important
Power output	Important	Important

sion or detonation. In diesel engines the fuel is injected gradually and should combine with air immediately after it is introduced into the cylinders. Otherwise the accumulated unburnt fuel may penetrate deeply into the combustion space and explode when present in a large quantity, thus shattering the cylinder walls. Combustion mechanism of diesel engines requires, therefore, the use of a highly explosive fuel. If such a fuel burns as soon as it reaches the combustion zone, a series of minute explosions thus produced creates a high compression wave while the individual explosions are too mild to have harmful effect on cylinder walls.

Conditions prevailing in diesel engines in general are greatly accentuated in high-speed models because the time allowed for fuel injection in a given engine decreases with the increase in rate of piston travel. In addition, flexibility of service required from these engines necessitates the use of selected fuels for assuring satisfactory engine performance.[19,48] Comparison of general requirements for gasoline and high-speed-diesel fuels is shown in Table 1. The information presented in this table shows that diesel fuel for high-speed engines must meet more individual tests than gasoline, which has a direct bearing on their manufacturing cost.

Ignition Quality

Ignition quality of diesel fuels includes properties related to easy starting, quick attainment of steady firing conditions, and smooth combustion. Similar ignition quality of gasoline is referred to as its anti-detonating or anti-knock characteristics.

The anti-knock characteristics of gasoline are evaluated in terms of octane numbers. Octane numbers refer to percent volume of iso-octane (2,2,4-trimethyl pentane) in mixtures with normal heptane showing an equivalent performance with the fuel tested. Iso-octane has excellent anti-detonating properties and is assigned a value of 100 on this scale, while normal heptane is a bad detonator and is assigned a value of 0.

Because of the aforementioned differences in the combustion mechanism in the two types of engines, heptane is the better and iso-octane the poorer of the above standard fuels for use in diesels. The "heptane" scale occasionally employed in the past for evaluating ignition quality of diesel fuels assigns, therefore, a value of 100 for normal heptane and a value of 0 for iso-octane. However, the scale is not very satisfactory for practical application because of wider limits needed for evaluation of diesel fuels, and interference with diesel-engine performance resulting from non-viscous and volatile nature of the two hydrocarbons. Two other substances were, therefore, proposed as standards for diesel fuel testing, namely cetene (1-hexadecene, $C_{16}H_{32}$) which was assigned the value of 100 on account of its excellent performance in diesels, and mesitylene (1,3,5-trimethyl benzene, $[CH_3]_3\ C_6H_3$) which was assigned the value of 0 because of its opposite characteristics. The new scale expressed the value of diesel fuels in "cetene" numbers representing percentages of cetene in comparative blends.

Mesitylene is difficult to obtain in chemically pure state and, as a result, it was soon replaced by alpha-methyl naphthalene ($CH_3 . C_{10}H_7$). Cetene is also difficult to prepare and is, moreover, unstable in storage, which suggested the substitution of cetane (normal hexadecane, $C_{16}H_{34}$). The new scale, now widely adopted, expresses diesel-fuel ratings in terms of "cetane" numbers. The relationship between the two scales has been established as follows:[3,24]

$$\text{cetane number} = 0.875\ \text{cetene number}$$

A number of test engines have been developed for evaluating cetane numbers of fuels.[23] Comparisons can be made on the basis of ignition lag, minimum quantity of air required for ignition, critical compression ratio, or other characteristics related to engine performance. The method adopted by the American Society for Testing Materials is known as the coincident flash-fixed delay method. Similarly to the experiences with testing anti-detonating properties of gasolines, engines used in diesel oil testing do not give uniform results, i.e., cetane numbers of fuels determined by one method may differ from those found by another method. For general correlation purposes the method employed in comparative studies should be, therefore, always specified.

Secondary reference fuels are available for laboratory use. In this country they were standardized by the American Society for Testing Materials and are distributed under the names of "Shell High Cetane Reference Fuel" and "Low Cetane Reference Fuel" (mixture of alpha- and beta-methyl-naphthalenes manufactured by Reilly Tar and Chemical Company). In England the fuels are distributed under the auspices of the Institute of Petroleum as "High-Ignition-Quality Reference Fuel" and "Low-Ignition-Quality Reference Fuel." The two latter fuels have 80.5 and 20.5 cetene numbers or 70.5 and 18.0 cetane numbers, respectively.[3]

In determining cetane numbers an error of ± 2 is not uncommon.[3]

The necessity for this may be visualized from the fact that the critical ratio method, for instance, produces results which may be as much as seven points higher than those obtained by the ignition-lag method in the important 40-50 cetane number range.[21] Similarly the motor-starting method gives cetane numbers that may be 27 percent higher than those determined by the latter method, showing at the same time much larger deviations from the average.[45]

Physico-Chemical Properties

Cetane numbers occasionally are approximated with a fair degree of accuracy by measuring certain physico-chemical properties of fuels[18] although the results may be misleading when applied to a large variety of products.[8,22,27,41] These correlations involve the use of boiling-point index,[42] viscosity-gravity constant,[30] spontaneous-ignition temperature,[37] parachor,[18] characterization factor,[21] aniline point,[26] dispersion,[11] and similar characteristics of fuels[8] expressing their relative degree of paraffinicity. The error arising from these approximations is explained by considerable differences in ignition qualities of hydrocarbons of relatively similar structures as determined

by these methods. If such correlations were sound, the aniline point could be expressed as a function of viscosity-gravity constant, or spontaneous-ignition temperature as a function of dispersion, which is known to be far from accurate.

Diesel Index

Probably the best known of the above indirect relationships is the Diesel Index[5] correlating performance of diesel fuels API gravity (°API) and aniline point in °F. (AP):

$$\text{Diesel Index} = \frac{(°\text{API})\ (\text{AP})}{100}$$

However, a number of other formulas has been developed recently claiming a higher degree of accuracy between the observed and calculated data than it is possible with the use of Diesel Index. The Institute of Petroleum in England made a comparative study of the various indices and recommends the use of Cetane Index which involves correlations of cetane numbers to API gravity (°API) and mid-boiling point of the fuel in °F. (MB) (15):

$$\text{Cetane Index} = 175.4 \log (\text{MB}) + 1.98\ (°\text{API}) - 496$$

A large number of experiments conducted for testing validity of this relationship showed that Cetane Index agreed within ± 2 cetane numbers for 66 percent of fuels tested. With 77 percent of fuels deviations were ± 3 cetane numbers, while 6 percent of fuels showed discrepancies larger than ± 5 cetane numbers. All such correlations obviously are invalid for use with fuels containing additives where a marked improvement in cetane numbers is obtained at a negligible change in physical characteristics of the mixture.

Various correlations between cetane numbers and physico-chemical properties of fuels were reported in the literature.[17, 20, 23, 46] Table 2 has been prepared by using some of such data[21, 46] from average values in the most important 30- to 60-cetane-number region, using the delay (DM) and critical-compression-ratio (CCRM) methods for measuring actual ignition qualities of fuels. Inspection of these data reveals certain discrepancies which can be attributed directly to the difficulties involved in such comparisons. For instance, blending octane numbers and their opposites, heptane numbers, are by no means in close agreement. Similar variations will be observed if diesel indices are compared with the cetane numbers after the two sets of data are adjusted to a uniform basis.

Although cetane numbers indicate ignition qualities of fuels,[38] little if anything is gained by employing fuels having cetane numbers higher than those for which engines are designed,[12, 31] as there cannot be a further improvement in combustion after reaching mechanical limitations. This is in accord with similar experiences with octane ratings of gasolines employed in automobile motors where merits of high-octane fuels can be demonstrated in high-compression engines specifically designed for their use.

Cetane-number requirements for fuels employed in various types of diesel engines are approximately as follows:

High-speed diesel engines — about 50-cetane number
Medium-speed diesel engines — about 45-cetane number
Low-speed diesel engines — about 40-cetane number

Load Conditions

However, the tabulated data refer to most severe conditions which may be encountered in service. Under different loading conditions the same engine may be operated on fuels of considerably lower cetane numbers as demonstrated by the following experiments involving the same engine.

It is also of interest that when the engine is loaded,

Operating Conditions	Minimum Cetane Number Requirements
Full load	25
One-third load	30
Idling	35
Starting from cold	35
Smooth combustion	45

wide variations in speed do not tend to produce misfiring.

Manufacturers of engines of intermediate type between diesel and gasoline engines frequently specify both lower and upper permissible limits for cetane numbers of fuels. The upper limit is usually restricted to a 60-cetane number.

Cetane numbers of diesel fuels obtained from American crude oils vary between 30 and 65.[36, 46] They are considerably lower for cracked distillates obtained from the same crude oils as the virgin stocks because cracking reduces their paraffinicity. However, catalytic cracking is capable of producing distillates with cetane numbers only slightly lower than those of virgin gasoils from Pennsylvania and Mid-Continent stocks, and with yields as high as 55 percent on the charge to the unit.[32]

Representative cetane numbers for diesel fuels obtained from various crude oils are approximately as follows:

Pennsylvania — 65-cetane number
Mid-Continent — 55-cetane number
California — 45-cetane number
Coastal — 35-cetane number
Mirando-O'Hern — 28-cetane number

Cetane numbers of individual fractions from each crude are not constant, however, but vary with the

TABLE 2

Approximate Relation Between Cetane Numbers and Physico-Chemical Characterization Constants of Diesel Fuels

Characterization Constants	CETANE NUMBER							
	DM				CCRM			
	30	40	50	60	30	40	50	60
Blending Octane No.	51	35	19	2	56	43	30	13
Boiling Point—Gravity No.	201.0	190.6	183.4	177.6	204.1	195.3	188.0	181.5
Cetane No. (CCR)	34	46	57	66	....	....	....	....
Critical Compression Ratio*	....	....	....	....	11.1	8.6	8.1	7.6
Diesel Index	19	37	53	65	14	23	42	56
Heptane No.*	....	....	....	....	40	87	....	....
UOP Characterization Factor	10.79	11.33	11.60	11.95	10.55	11.06	11.44	11.77
Viscosity—Gravity Constant	0.925	0.870	0.842	0.823	0.936	0.892	0.859	0.834

* Approximated from data obtained by Wilson (47). The rest of the data taken from average curves plotted by Hubner and Murphy (21).

boiling point of the distillates.[2] They are lower for extreme-boiling fractions as compared to the intermediate ones. It is of interest that heavy fuels from alkylation processes have a cetane number as low as 24, while their Diesel Index is as high as 95.[2]

Comparing these cetane numbers of various refinery fuels with those required by the high-speed diesel engines, it may be easily seen that by no means all of the products of desired boiling point or viscosity specifications can be converted into high-grade diesel fuels. Even the majority of the virgin gasoils, as represented by other than Mid-Continent and Pennsylvania stocks, are not capable of yielding fuels of 50-cetane number or higher. This is in itself a considerable handicap particularly because crude oils best suited for diesel-oil manufacture are at the same time of the lubricating-oil type usually sold at a premium.

Addition Agents

A large number of addition agents has been developed recently for improving the cetane number of diesel fuels. These addition agents include alkyl nitrates, nitrites or peroxides, nitroso compounds, ethers, sulfur and some of its derivaties, as well as a number of other substances. Most of them are of highly explosive nature which is to be expected from the desired combustion characteristics of diesel fuels discussed at the beginning of this article. In general, these addition agents reduce ignition lag and the rate of pressure rise in cylinders. They are ineffective for improving the power output,[43] although a few of them, such as tetranitromethane, may possess slight advantages in this connection. On the other hand substances are known which increase power output by a few percent but retard ignition.

As it was previously mentioned, improvement in cetane number has a beneficial effect on ignition qualities of diesel fuels. This does not imply, however, that both starting characteristics and combustion properties are equally affected. Although ease of starting may show a general relation to cetane number,[1] their interdependence is by no means well defined,[16] suggesting that other factors may be of equal or even greater importance.[13, 39] For this reason some of the cetane-number improvers, like ethyl nitrate, are helpful for insuring smooth combustion but not starting, while others, like chloropicrin, may improve both.[35] Starting characteristics are very important, however, as normal fuels do not permit starting at temperatures much below 20° F.[13]

Results of experimental work demonstrated that at 40° F. a blend containing 3 percent secondary amylnitrate started the engine in the same length of time as straight-mineral-oil fuel of similar cetane number. At 20° F. the blend containing amylnitrate had to have a cetane number of 59 in order to make it comparable in this respect with a straight-mineral-oil fuel of 52-cetane number. At 13° F. similar performances were obtained with resulting cetane numbers of 75 and 60, respectively.[13]

The use of addition agents in diesel fuels has been a subject of many investigations in the course of the last several years in view of their possible practical importance. However, the early expectations of finding an agent of equal importance to tetraethyl lead for gasolines have not yet been realized. Since the major justification for employing high-speed diesels in preference to gasoline engines is the saving in fuel cost, the use of cetane number improvers, which are generally expensive, is a step in the wrong direction and is difficult to justify economically.

Viscosity and Distillation Range

Ease of atomization depends mainly on fuel viscosity and distillation range. As viscosity increases with the increase in boiling point, either one of these properties is indicative of atomizing characteristics of fuels, provided the type of crude oil is not radically different. The inclusion of minimum-flash point in diesel-fuel specifications is of no meaning whatsoever in this connection, and is of doubtful value for estimating fire hazard, because the presence of small quantities of low-boiling constituents have a very large effect on flash point irrespective of the boiling point characteristics of the main bulk of fuel-oil constituents. Fuels for high-speed diesels usually have a viscosity of 30 to 35 Saybolt Universal seconds at 100° F., representing a refinery fraction boiling just above kerosine. This fraction is a valuable one even from non-lubricating-oil crudes as it can be easily converted into gasoline by cracking. For this reason diesel fuels of the required type cannot be prepared from low-grade materials but must carry a certain premium arising from their potential possibilities as sources for gasoline production.

Carbonizing tendency of high-speed diesel fuels is determined in the laboratory by the carbon-residue test. Because of the very small quantities of carbonaceous deposits obtained from distillate stocks in these inspections, carbon residue usually is determined on 10-percent distillation bottoms[28] in order to improve the experimental accuracy. Claims were advanced that such relationships are quite pronounced.[7, 10, 25] However, the test fails to differentiate between the physical characteristics of the carbon formed. Small quantities of hard carbon are much more detrimental to the engine than large volumes of fluffy carbonaceous deposits which are eliminated through the exhaust. For this reason the carbon-residue test frequently is misleading. The carbon-residue specifications require care in preparing stocks by eliminating possible entrainment in the course of distillation and by avoiding contamination with residual oils. The presence of small amounts of very heavy distillates has no adverse effect, however, on fuel performance.[12] Ash content also has an effect on formation of engine deposits, but its presence is concealed as it is automatically included in the carbon-residue test. Based on lubricating-oil experience, presence of ash may be helpful in forming fluffy deposits, although it has to be avoided because of wear of equipment. Ash usually arises from incomplete removal of neutralization products after acid and caustic treatment, requiring careful washing with water those diesel fuels which were subjected to such refining procedures. Although carbon residue is normally included in diesel-oil specifications, control of carbon deposits is more a matter of engine design than fuel quality or operating variables,[29] and should decrease in importance with future progress in engine construction.

Fluidity is controlled by viscosity and pour-point of the oil. It determines the ease of fuel flow to the combustion zone and is, therefore, of particular importance for low-temperature operations. Viscosity

is seldom a problem in high-speed-diesel fuels because maximum permissible limits for insuring satisfactory atomization are sufficient protection. However, pour point, controlled by the quantity of paraffin wax present, is important and must be kept at a minimum in order to prevent congealing of the fuel at temperatures below the crystallization point of wax. The problem is aggravated by the fact that high-cetane-number fuels are paraffinic in nature, and they necessarily are produced from crude oils carrying large quantities of wax.

Difficulties involved in production of high-grade diesel fuels may be visualized from the fact that pure materials having cetane numbers above 80 cannot be used in sub-zero weather because their melting points are above 0° F.[13] The necessity of removing such constituents from diesel fuels (resulting in lowering of cetane number) prevent inclusion of low-cetane-number materials which would be possible otherwise.

Dewaxing Impractical

Removal of wax from diesel fuels by common dewaxing methods applied in lubricating-oil manufacture is impractical because of the expense involved. Similar economic considerations prevent the use of pour-point depressants of Santopour or Paraflow type. As a result the refiner has to choose between fuels of low viscosity and, therefore, free of wax associated with the high-boiling crude-oil fractions, and fuels containing certain amounts of cracked distillates from which wax has been eliminated by cracking. The first alternative lowers lubricating properties of diesel fuels which are important for satisfactory operation of certain types of engines, while the second alternative results in lowering of cetane number and affects unfavorably the fuel stability.

Cleanliness of diesel fuels, i.e., freedom from water and sediment, insures against line plugging and is an additional guarantee for satisfactory engine performance.[33] Besides being a non-combustible material, water may have a deleterious effect on the combustion mechanism as its presence retards flame propogation through the air-fuel mixture. Water may cause also corrosion of containers and lines through which the fuel has to travel. Elimination of sediment and water necessitates considerable precautions in handling fuel before it reaches the customer.

Stability of diesel fuels is important if they are stored for some time before use. Present specifications usually omit these requirements, but tests similar to those used for determining gum content of gasoline are already in the state of development. Virgin fuels generally are stable and no difficulty is experienced in this connection. However, the use of cracked products in diesel fuels for reasons already explained as well as by the necessity of increasing sources of their supply, explains the desirability of introducing the gum-test specifications.[14, 33] This will result in an increase in the manufacturing costs of diesel fuels because of additional treatment required.

Corrosiveness of diesel fuels may be due to the presence of water, free organic acids or excessive sulfur content. The fuels usually are required to pass copper-strip corrosion test and their maximum sulfur content also is specified. The latter requirement prevents the use of inexpensive sulfur or sulfur compounds as cetane-number improvers. Besides corrosiveness, the presence of large quantities of sulfur compounds may cause ring sticking and formation of varnish deposits in the engine.[12] Presence of ash does not affect corrosive properties of fuels but results in rapid abrasion and wear of injection pump and nozzles.

Lubricating properties of diesel fuels which control their lower permissible viscosity limits are necessary for satisfactory performance of certain types of injection pumps. Although kerosine works satisfactorily in some diesel engines and gasoline or even hydrocarbon gases may be utilized for this purpose,[9] they cannot be employed indiscriminately as all-purpose diesel fuels. In addition, the cost of fuels generally increases with the increase in their volatility, gases excepted. An increaes in fuel viscosity has also a tendency to decrease leakage because of improved sealing characteristics.

Absence of smoke and odor is important for high-speed diesel engines operating in congested districts. Smoking tendency results from incomplete combustion of fuel which may be due both to mechanical condition of the engine and to the type of fuel employed. This tendency is higher for fuels of low cetane number, poor volatility, high viscosity and high carbon residue.[1] Odor from exhaust arises mainly from the presence of aldehydes in the exit

The oil industry is a big user of the heavy trucks that are large users of diesel fuel.

gases and is claimed to be directly dependent on cetane number of fuels, which is a measure of the ease of attaining complete combustion.[1, 44] However, the presence of sulfur or certain nitrogen-sulfur compounds also influences the odor of the exhaust[40] due to formation of sulfur dioxide and other pungent combustion products. For this reason direct relationship between cetane number and the exhaust odor may not hold necessarily for all types of diesel fuels. Odors arising from sulfur and nitrogen-sulfur compounds may be eliminated by treating fuels with chlorine or active oxygen.[40] The use of low-boiling fuels, such as kerosine, reduces the smoking tendency and is a favored remedy of many fleet operators although it increases their operating expense. Smoke and odor are particularly pronounced when the engine is idling, or when it is rapidly accelerated after idling, or decelerated with the clutch engaged with the engine.

Fuel Economy

Fuel economy, i.e., mileage, depends on the heat content of the fuel. For either constant gravity or cetane number, an increase in mid-boiling point increases the heating value of fuel on volumetric basis. At low speeds, lowest consumption is obtained with fuels of highest heating value, while at high speeds cetane number becomes of greater importance for fuel economy. Low-viscosity fuels show somewhat higher consumption than might be expected from their heating values.[6] However, the differences between the various fuels are small and may be neglected because other factors have a greater effect on mileage than heating value of fuels. This may be seen from the following test data:

FUEL	Fuel Consumption Percent		Lbs./Gallon Percent	Heat Content Btu/Gal. Percent
	Weight Basis	Volumetric Basis		
High-cetane, straight-run	100	100	96	98
Medium-cetane, straight-run	98	100	95	96
Low-cetane, cracked	95	98	100	100

The above data show that the consumer has little to choose between the three fuels on mileage basis alone.

Power output depends to a great extent on boiling-point characteristics, i.e., the ability of fuel to form intimate mixture with air, and complete the combustion process irrespective of the rate at which the fuel is injected.

The relative effect of the different variables discussed depends to a great extent on engine design. However, savings in the manufacturing expense of cheap fuels is more than counterbalanced by the increased distribution and storage costs arising from the necessity of handling several products. For these reasons the cost of fuels for high-speed diesel engines is now by necessity high, approaching and occasionally surpassing the cost of gasoline. The complex specifications for such all-purpose fuels even led to studies of the possibilities of preparing them synthetically,[34] which indicates that the margin between their cost and the cost of gasoline decreased to a point when complicated processing may not be entirely out of consideration. The decreased differential between the gasoline and diesel-fuel cost during the last few decades is explained by the progress made in gasoline manufacture and development of cracking processes. In 1920 the average cost of gasoline was 24 cents, while in 1940 it dropped to 9 cents per gallon, exclusive of taxes.

Originally some savings could be effected by the use of tax-free products. However, most of the states ceased to make differentiation between gasoline and diesel fuel for highway vehicles and some of them even impose a higher tax on diesel fuels. The federal tax is levied on gasoline only.

Future utilization of high-speed diesel engines for trucks and busses thus depends to a considerable extent on further mechanical developments leading towards utilization of cheap fuels which is contrary to present trends. Less than one percent of the above vehicles is now equipped with diesels, thus leaving practically the entire field open for economic competition with the gasoline engines. This percentage certainly can be increased if diesel fuel specifications are made less stringent and the distribution problems simplified by eliminating several grades of fuels, handling of which involves a considerable expense. This is of particular importance in view of the small demand for such fuels prohibiting the use of simplified methods now widely adopted for handling gasoline.

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The Laboratory Is Essential in

Blending Residual Fuel Oil

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SINCE the beginning of the war there has been an ever-increasing demand for fuel oils of all grades, and especially for Navy fuel. This requirement has had to be met with fuels from crudes of lower quality. When blending residuals with cutter stocks to meet strict specifications, there is no assurance that the oils will mix successfully until the information has first been obtained from the laboratory. Depending on the stocks, there is always some one specification that is the most difficult to meet and this, of course, is the one for which the blend is made. Time can be saved and fewer trial blends made, if the tests on the blend can be calculated from tests on the oils to be used.

API gravity has no particular significance as a specification, although it must be known to determine the coefficient of expansion to be used in volume corrections, and the specific gravity which is used in weight calculations. In calculating the gravity of a blend the specific gravities of the components should be used instead of the API gravities. As an example, suppose it is desired to know the API gravity of a blend composed of 100 barrels of 30.0°-API-gravity oil and 200 barrels of 15.0°-API-gravity oil.

30.0° API = 0.8762 Specific Gravity at 60/60° F.
15.0° API = 0.9659 Specific Gravity at 60/60° F.

$$\frac{(100 \times 0.8762) + (200 \times 0.9659)}{300} = 0.9360 = 19.7° \text{ API.}$$

If the API gravities were used, the result would be 20.0° API, which is too high.

The API gravity is also used in formulae for estimating the heating value of oils. Scott[1] gives the formula:

Gross Btu per pound = 17,780 + (54 × API), for cracked fuels, and
Gross Btu per pound = 17,660 + (69 × API), for straight-run fuels.

The gross or higher heating value is the laboratory determination of the heat of combustion in a calorimeter with total condensation of water at 60°F. The net or lower heating value represents the heat of combustion found by considering the water formed during combustion to remain in the vapor state. The difference between the higher and lower heating values is the latent heat of the water formed which is 1030 Btu per pound at 60°F. Since in actual use the water from combustion is not condensed, the lower value will more nearly correspond to the amount of heat obtained. Cracked fuels have a lower gravity and fewer Btu per pound than straight-run fuels of the same viscosity; however, the heavier the fuel oil, the more Btu it has per gallon. This is shown by substituting in the above equations, for example, 10° API (8.328 pounds per gallon) for cracked fuel and 15° API (8.044 pounds per gallon) for straight-run fuel. For the cracked fuel the gross heating value is 18,320 Btu per pound, or 152,569 Btu per gallon, and for the straight-run fuel it is 18,695 Btu per pound, but only 150,383 Btu per gallon.

The flash point of an oil indicates the temperature at which it will give off enough vapors to form an inflammable mixture with air. It is an important test and should be higher than the temperature to which the oil is to be heated. The flash point of a blend cannot be calculated satisfactorily from the tests on the two stocks, although it will be somewhere between them, and, in the case of a blend of equal volumes, it will be closer to the lower than to the higher flash point, and not halfway between as might be expected.

Pour Point

The pour point is the lowest temperature at which the oil will flow when cooled under the specified conditions of the test. Cracked fuels usually have a lower pour test than straight-run fuels of the same viscosity, and this is especially desirable in a cold climate. The pour point of a blend can only be estimated as in between the tests of the two stocks. If heat has been used in making the blend, special care should be used in following the ASTM procedure in determining the upper or maximum pour point; otherwise, a low and misleading test may be obtained.

Sulfur

When the sulfur content is over 2.5 percent the fuel is either a residue from a high sulfur crude, or a mixture of fuels containing sulfuric acid sludge. Sulfur itself burns, and so is not completely worthless as a fuel, but it is nevertheless an undesirable impurity due to the corrosive action of the stack gases. The sulfur content of a blend can be calculated quite accurately from the sulfur contents of the stocks used; it is reported as a weight-percent so that corresponding weights or weight percentages must be used in the calculations. For example, suppose it is desired to know the sulfur content of a blend composed of 100 barrels of 30-API-gravity oil, 0.80 percent sulfur, and 200 barrels of 15-API-gravity oil, 1.50 percent sulfur:

$$\frac{(100 \times 0.8762 \times 0.80) + (200 \times 0.9659 \times 1.50)}{(100 \times 0.8762) + (200 \times 0.9659)} = 1.28\% \text{ sulfur.}$$

Residue

The carbon residue test gives some idea of the relative carbon-forming tendencies of oils and can readily be calculated from the tests on the blending stocks, being careful to use weight percentages and not volume percentages of the stocks.

The ash test indicates the amount of non-combustible matter present in the oil, and it can be calculated from the tests on the blending stocks, using weight percentages. The ash content should be kept as low as possible because of its destructive action on the pumps, valves, burners and furnaces. In some cases low-ash fuels are available for blending with the high-ash fuel. However, where the ash is due to chlorides, control of this factor may involve a desalting operation on the crude oil which would have the

TABLE 1

Viscosity of Fuel at 122° F. Saybolt Furol	Preheating Temperature (°F.) to Get Viscosity of 130 Seconds Saybolt Universal
25	150
50	175
100	197
150	210
200	218
300	227

added advantage of reducing corrosion in the distillation equipment. When it is necessary to distill crude oils containing naphthenic acids in the presence of caustic soda, the residual fuel sometimes has such a high ash content of sodium salts that it cannot be used because of the destructive action of the alkaline residue on the furnace refractories. Scafe, Hayden and Kalichevsky[2] propose the treatment of such oils with boric acid to form oil-insoluble sodium borates which settle out as a sludge from which the boric acid may be recovered by acidification with sulfuric acid sludge. The cost of treatment is said to be low.

Viscosity

The viscosity of an oil is a measure of its resistance to flow, and is of considerable importance in fuel oils because of its effect on the ease of pumping and on the degree of atomization that can be obtained. The standard temperature for viscosity tests on fuel oils is 122°F. on the Saybolt Furol instrument, and, whenever the time of outflow is less than 25 seconds, the Saybolt Universal instrument is used. To get the best atomization in the burner, a fuel should have a viscosity less than 130 seconds Saybolt Universal. Viscosity decreases rapidly with increased temperatures so that preheating permits the use of oils of higher viscosity than would otherwise be possible. Table 1 shows the temperature to which it is necessary to heat California cracked fuels of various viscosities in order to get a viscosity of 130 seconds Saybolt Universal.

In making the fuel-oil blend, the viscosity specification is usually the most important from the standpoint of economics since the gasoil used in the blend is more valuable than the residual fuel. Consequently, no more gasoil is used in the blend than is necessary to meet the viscosity specification, provided, of course, that all of the other physical tests will also pass. The curves in Figure 1 show what large amounts of distillates are required to make fuels in the lower viscosity range. The necessity of using these large amounts of cutter stocks sometimes creates the greatest problem in making the blend, that of stability.

B.S.&W.

An emulsion of water, oil and sediment will settle out of practically all fuel oils in storage tanks. Water present in an oil can be determined quite accurately by the distillation test, and it can be calculated on a blend from the tests of the stocks. Volume percentages are used here. The B.S.&W. test gives some idea of the potential sludge formation in storage tanks, but the actual amount and rate of settling of these deposits depends upon the type of oil and the nature of the emulsion. The cracked residuals before blending are usually as stable as the straight-run residuals, but the solubility of cracked residuals in most distillates is lower, which is shown by the B.S.&W. tests in Table 2 made from tests of laboratory blends. If the two oils used in making the blend are completely soluble in each other, the B.S.&W. test can be

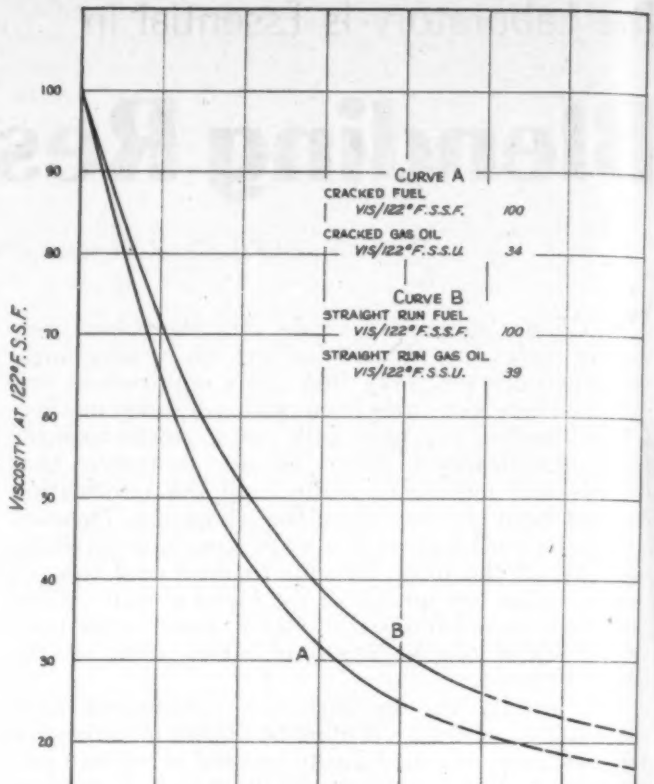


FIGURE 1

Fuel oil-gasoil blending chart—Wilmington and Signal Hill crude oils

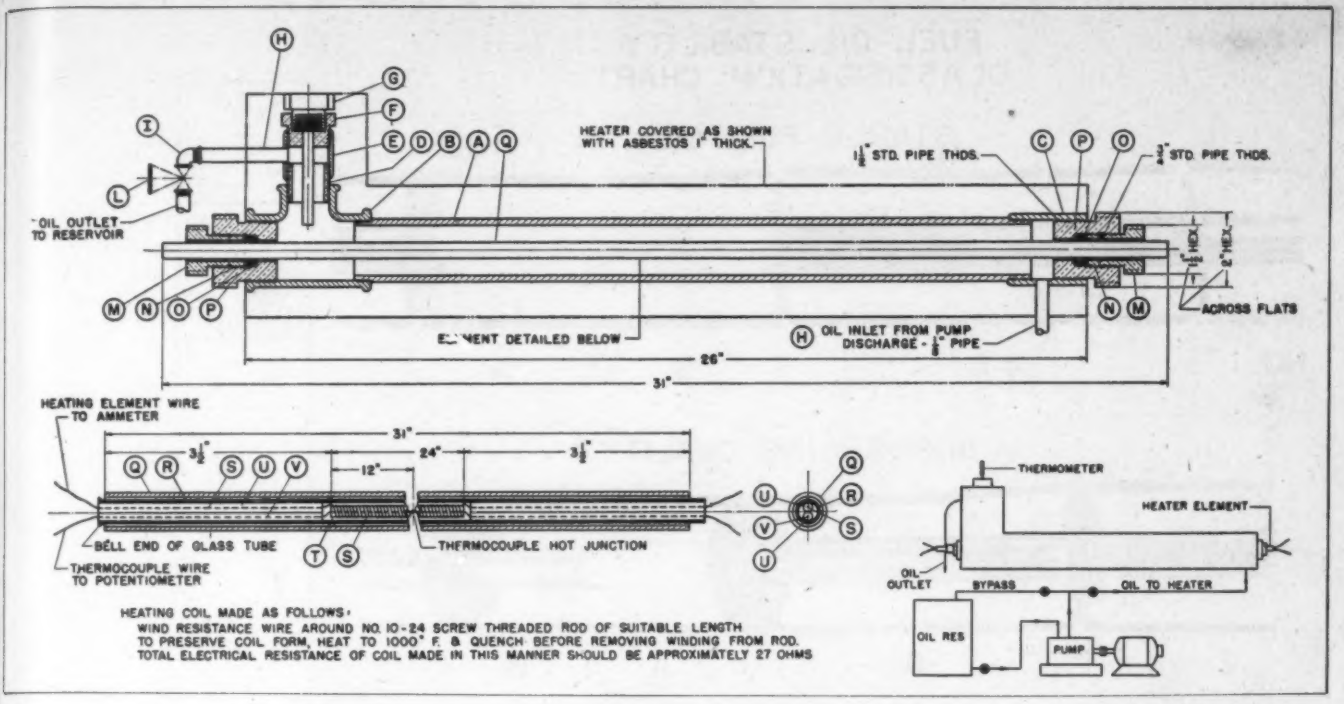
calculated. This is usually the case when straight-run residuals and distillates are used. However, cracked fuels are not always completely soluble in petroleum distillates, either cracked or straight-run. This is particularly noticeable when large amounts of distillates are used in the blend, as in Table 2. The first six blends were made at room temperature, the seventh was made at 150°F., which indicates somewhat better solubility at higher temperatures.

Of course such instability as shown by Blends 3, 4, and 7, would be intolerable in any fuel. The lower solubility of cracked residuals is due to the presence of heavy asphaltenes, which are more easily precipi-

TABLE 2

	Percent B.S.&W.
Straight-run Fuel Oil	0.10
Straight-run Distillate	Trace
Cracked Fuel Oil	0.50
Cracked Distillate	0.05

Blend			Percent B.S.&W.
1	Straight-run Fuel Straight-run Distillate	50% 50%	0.05
2	Straight-run Fuel Cracked Distillate	50% 50%	0.1
3	Cracked Fuel Straight-run Distillate	40% 60%	6.0
4	Cracked Fuel Cracked Distillate	30% 70%	3.4
5	Cracked Fuel Straight-run Fuel	50% 50%	0.3
6	Mixed Fuel [3] Cracked Distillate	40% 60%	0.2
7	Cracked Fuel Cracked Distillate	30% 70%	2.4



HEATING COIL MADE AS FOLLOWS:
WIND RESISTANCE WIRE AROUND NO. 10-24 SCREW THREADED ROD OF SUITABLE LENGTH TO PRESERVE COIL FORM, HEAT TO 1000° F. & QUENCH BEFORE REMOVING WINDING FROM ROD. TOTAL ELECTRICAL RESISTANCE OF COIL MADE IN THIS MANNER SHOULD BE APPROXIMATELY 27 OHMS

tated by the blending distillates than those found in straight-run residuals. Blend 6 indicates that the addition of straight-run residuals to cracked residuals before blending with distillates markedly increases the solubility. It has been shown by Batchelder and Wellman[3] that this is due more to a protective action on the collodial binders holding the asphaltenes in suspension than to a solvent action.

The principal objection to the use of cracked-fuel blends has arisen from the fact that the amount of sediment deposited on the preheaters has been erratic and unpredictable, whereas, straight-run fuels gave good service in this respect. The sediment by extraction test, using benzol, has been specified on fuels for years, and, although it gives some indication of the amount of potential deposition of sludge in storage tanks, it is of very little use in determining the deposition on preheater surfaces. There are a number of tests that can be applied to the oils to be blended that give useful information, as to whether or not they are mutually soluble. Hulse and Thwaites[4] recommend, instead of the sediment by extraction test, the use of hot filtration followed by washing with a high-flash-point paraffinic naphtha, since this avoids the use of benzol as a solvent which might dissolve the compounds not soluble in the oil itself. The Oliensis spot test can be applied, but gives only a qualitative indication of heterogeneity which does not necessarily indicate instability. Batchelder and Wellman[3] recommend the use of the percent cyclohexane-insoluble less the percent benzol insoluble material as a quantitative measure of the cracked residual content of a fuel. The aniline point of the blending distillate is very important. Batchelder[5] has shown that stable cracked residuals are miscible with large proportions of low-aniline-point distillates, but that the tolerance for high-aniline-point distillates is very small. However, only an actual service test can give the final answer to the question of stability.

PC.	NAME OF PIECE	MATERIAL	SPECS.
A	HEATER SHELL 1½" STD. PIPE	WROT IRON	44-P-11
B	TEE 1½" x 1½" x 1"	IRON	45-F-5
C	COUPLING 1½"	IRON	45-F-3
D	NIPPLE 1"	IRON	44-P-11
E	COUPLING 1"	IRON	46-I-8
F	BUSHING 1" x ¾"	BRASS	45-F-2
G	THERMOMETER WELL ¾"	STEEL	
H	PIPE ½" STD.	BRASS	44-P-12
I	ELBOW ⅛"	BRASS	45-F-2
L	VALVE	BRASS	45-F-2
M	GLAND BUSHING	BRASS	45-F-2
N	PACKING RING	BRASS	
O	PACKING	¼" ROPE ASBESTOS	
P	GLAND BODY	BRASS	
Q	HEATER ELEMENT 31" LONG .540" O.D. x .049 THICK	STEEL TUBE	
R	GLASS TUBE 32" LONG 7/16" O.D. x 1/16" THICK	PYREX	
S	HEATING WIRE HOSKINS-RES. .980 KM./FOOT	NO. 22 BWG. CHROMEL	
T	INSULATORS SINGLE HOLE ⅛" O.D. x 4"	PORCELAIN	
U	INSULATORS SINGLE HOLE 5/32" O.D. x 4"	PORCELAIN	
V	THERMOCOUPLE	I.C.	

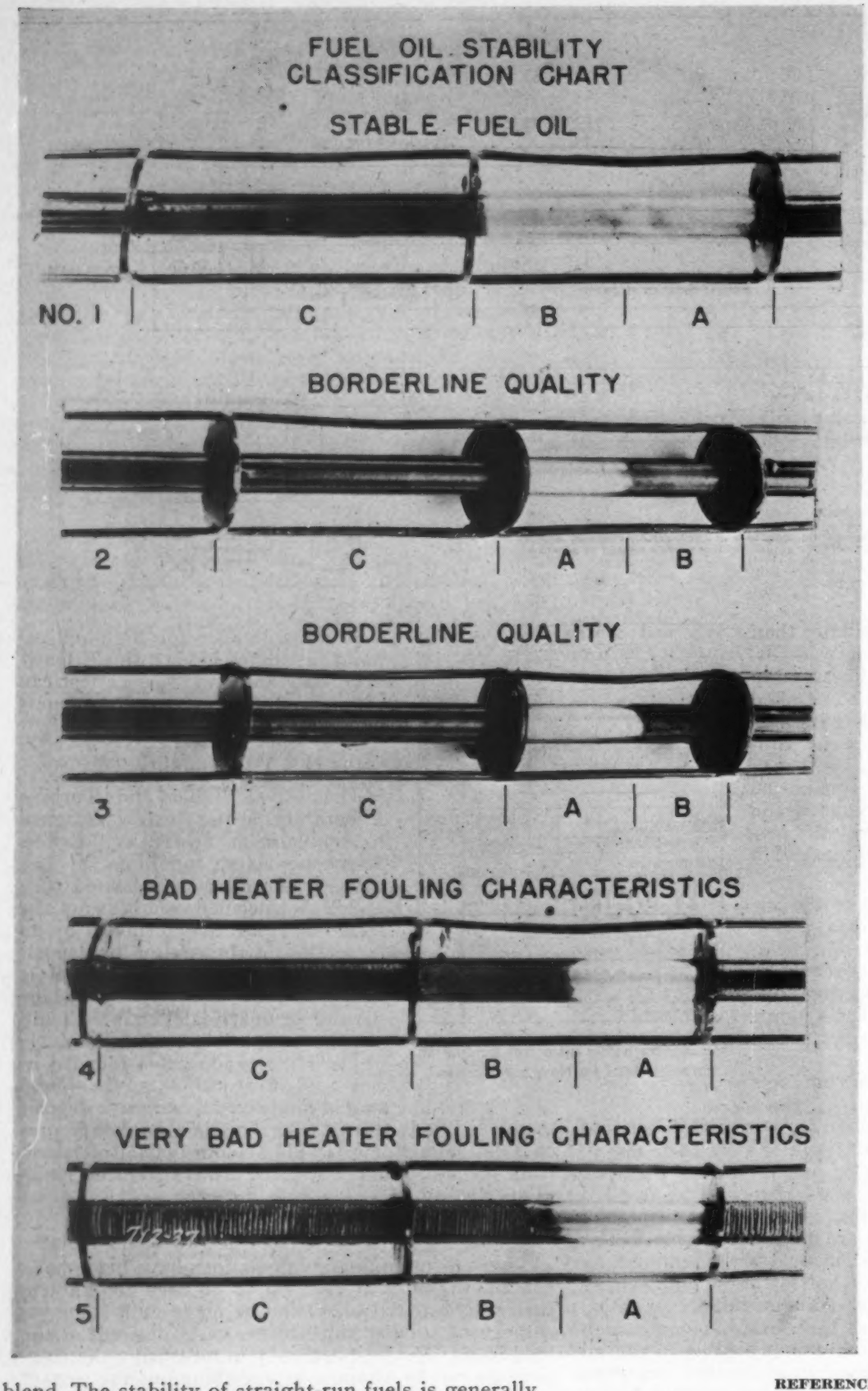
Laboratory heater apparatus for fuel oil stability tests for Navy specification.

N.B.T.L. Stability Test

The Naval Boiler and Turbine Laboratory heater test is designed to simulate, as nearly as possible, actual preheater conditions by circulating the oil over a heated tube under the specified conditions of the test. The result is determined by an inspection of the coating or deposit on the heater tube, and the oil is then classified as being stable, border-line or unstable. The fuel should also be compatible with other fuels of the same grade when blended in a 1 to 1 ratio; that is, the blend should not leave an excessive deposit in the N.B.T.L. heater test. This is a necessary precaution, since a ship would seldom get all of its oil from the same source and not always from even the same locality.

Making the Blend

After the preliminary calculations have been made and the volumes of each oil to be used are known, then the first trial blend can be made with some assurance of coming close to the tests desired on the final blend. The best accuracy in measuring the components can be attained by weighing out the correct volume of each, instead of measuring them volumetrically. It is generally advisable to have the oils hot while mixing, and to add the distillate stock slowly to the residual while stirring the mixture, because, in this way, the maximum percentage of distillate in the blend will not be reached until it has all been added. It should always be borne in mind that the quantity and quality of the blending distillate is the principal factor governing the stability of the final



Navy Fuel Oil Stability Classification Chart.

A—Benzol-washed section 4 inches in length after wiping with cloth.

B—Unwiped but benzol-washed section 4 inches in length.

C—Appearance of the steel tube after removal from heater shell.

blend. The stability of straight-run fuels is generally not affected by the addition of distillates, but stable cracked fuels will tolerate only very small proportions of straight-run distillates and only moderate proportions of most cracked distillates. When cracked residuals have to be severally cut back, it is sometimes advantageous to first blend straight-run residual with the cracked residual and then blend to viscosity with the cracked distillate.

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[1] Scott, "Standard Methods of Chemical Analysis," 5th Ed., Vol. 2, p. 1764.

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[3] A. H. Batchelder and H. B. Wellman, "Identification and Properties of Straight-run and Cracked Residual," Ref. and Nat. Gaso. Mfgr., Vol. 17, No. 6, p. 280.

[4] S. H. Hulse and H. L. Thwaites, "Determining the Sediment Content of Fuel Oil," I.E.C., Anal. Ed., Vol. 10, No. 12, p. 678.

[5] A. H. Batchelder, "The Stability of Residual Fuels," Ref. and Nat. Gaso. Mfgr., Vol. 15, No. 11, p. 485.

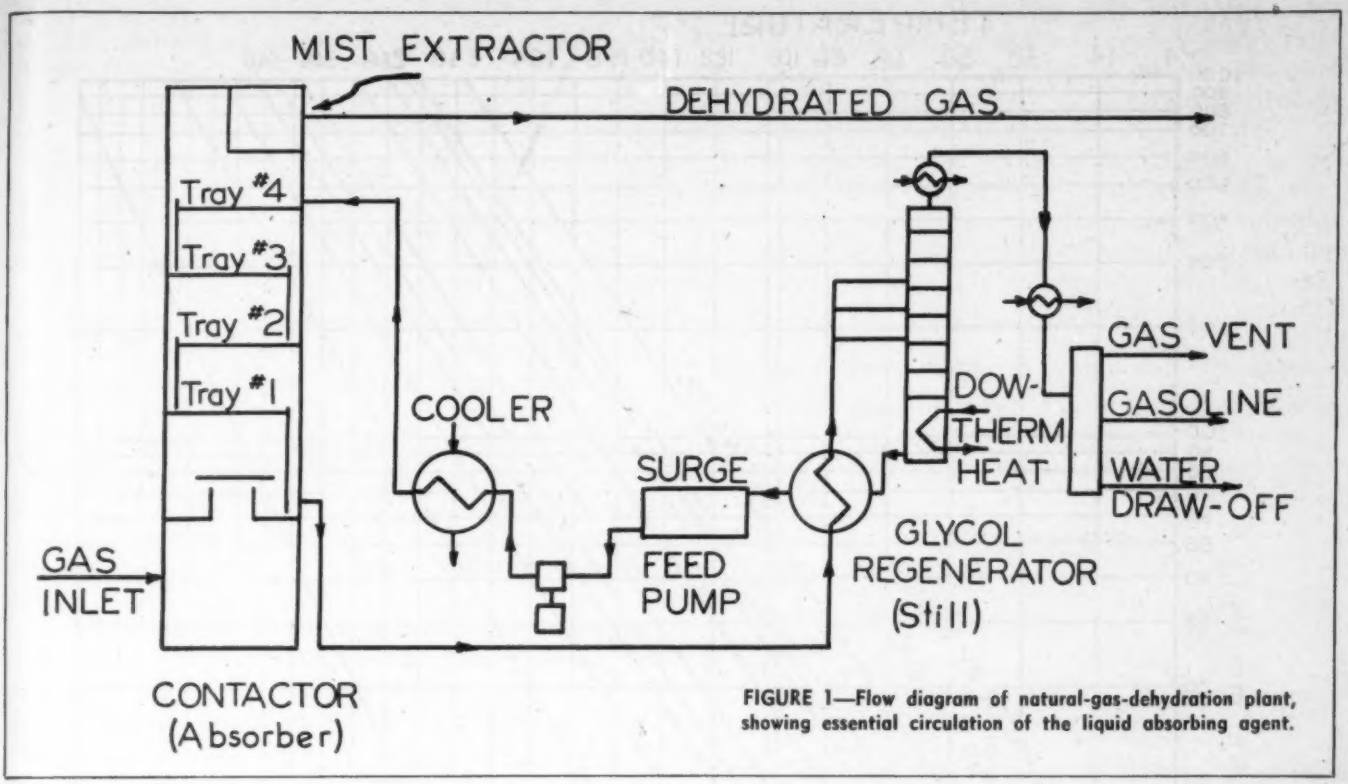

FIGURE 1—Flow diagram of natural-gas-dehydration plant, showing essential circulation of the liquid absorbing agent.

Dehydration of Natural Gas With Diethylene Glycol

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School of Chemical Engineering, University of Oklahoma

NATURAL-GAS dehydration is important as an aid toward an uninterrupted flow of gas during the months of greatest demand, as well as a means for more efficient gas transmission and regulation. Though solid sorbents, such as activated alumina are widely used to remove the water vapor from the gas, this paper is confined to the use of a liquid absorbent for purposes of dehydration. Dehumidification is achieved by reducing the concentration of the water vapor present in the natural gas to a value sufficiently low to prevent the condensation of water vapor.

Contrary to popular belief, an efficient dehydration plant does not remove all water vapor from the gas, but only reduces the dew point to a temperature below any likely to be encountered by the gas at some future time. Since the weather is largely responsible for the temperatures encountered, except for temperature drops due to expansion at points of pressure reduction, it is not possible, for other than local conditions, to anticipate this temperature with a high degree of accuracy. In long transmission lines, a study of weather data for previous seasons, together with a study of gas temperatures prevailing, reveals the probable minimum temperature to which the gas may be subjected. Allowing for any changes in the compression ratio of the booster stations up the line, the most severe conditions are assumed in establishing the maximum water content allowable for the gas which is processed.

Liquid Dehydration—An Absorption Process

Fundamentally, natural gas dehydration by use of a liquid extracting agent is another application of selective absorption of a vapor by a liquid. For 25 years the natural-gasoline industry has been making use of a very similar absorption process in the recovery of gasoline from natural gas. Use is made of the same type of equipment in either case, the only difference between the two operations being the absorbing mediums and the size of equipment. For natural-gasoline extraction the absorbing medium is a relatively non-volatile liquid in which the gasoline vapor is soluble in all proportions. For water-vapor extraction it is likewise necessary to have an absorbing medium of low volatility, and one in which water is soluble in all proportions. Ideally, a non-volatile liquid capable of absorbing gasoline and water simul-

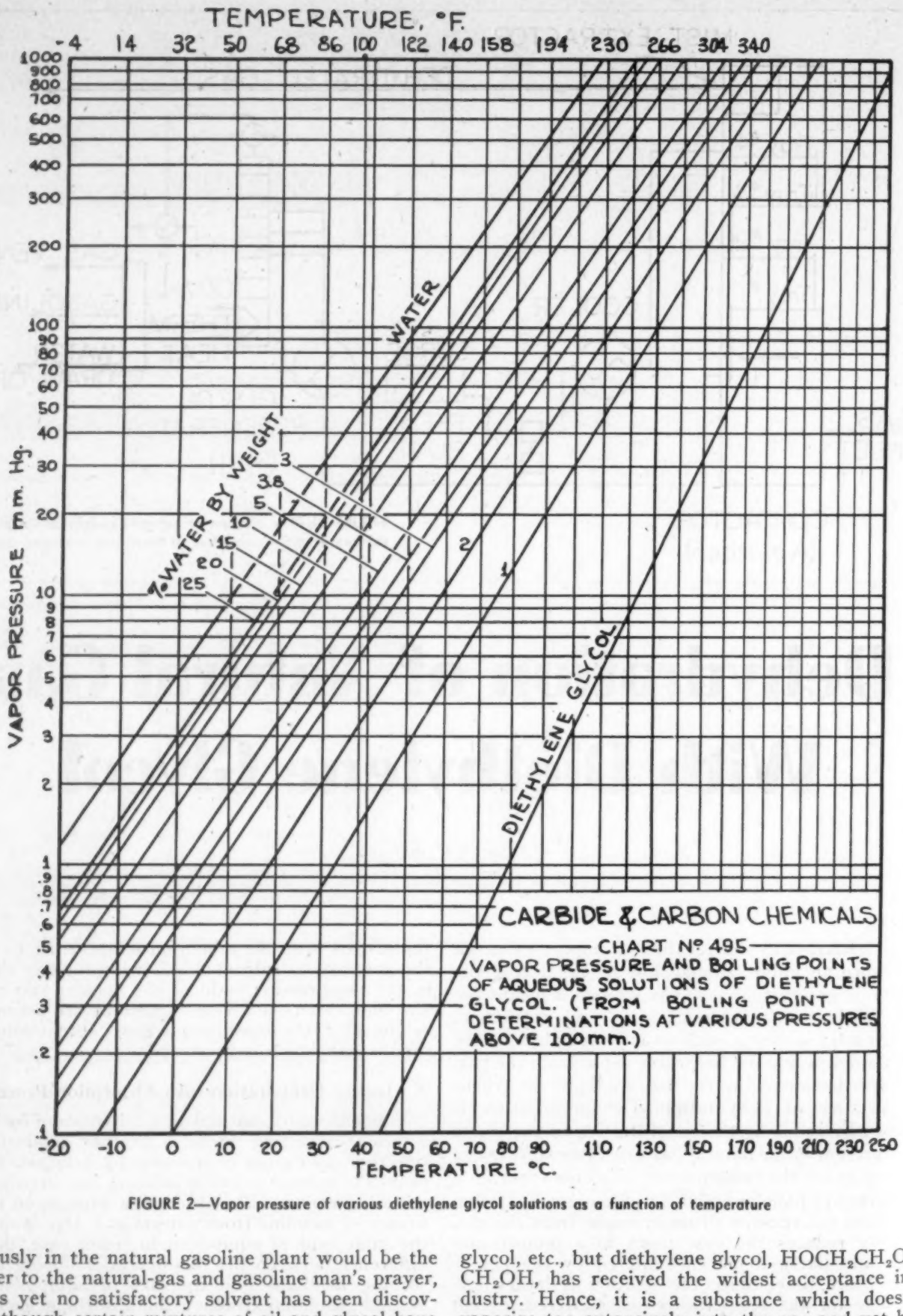
TEMPERATURE, °F.
-4 14 32 50 68 86 100 122 140 158 194 230 266 304 340
VAPOR PRESSURE mm. Hg.
1000 900 800 700 600 500 400 300 200 100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3 2 1 .9 .8 .7 .6 .5 .4 .3 .2 .1
WATER
% WATER BY WEIGHT
3
3.8
5
10
15
20
25
DIETHYLENE GLYCOL
CARBIDE & CARBON CHEMICALS
CHART Nº 495
VAPOR PRESSURE AND BOILING POINTS OF AQUEOUS SOLUTIONS OF DIETHYLENE GLYCOL. (FROM BOILING POINT DETERMINATIONS AT VARIOUS PRESSURES ABOVE 100 mm.)
-20 -10 0 10 20 30 40 50 60 70 80 90 110 130 150 170 190 210 230 250
TEMPERATURE °C.

FIGURE 2—Vapor pressure of various diethylene glycol solutions as a function of temperature

taneously in the natural gasoline plant would be the answer to the natural-gas and gasoline man's prayer, but as yet no satisfactory solvent has been discovered, though certain mixtures of oil and glycol have been proposed for this type of operation.

Nevertheless, there are several available absorbing mediums which fill the above requirements for water extraction, e.g. monoethanolamine, di- and triethanolamine, glycerine, ethylene glycol, triethylene glycol, etc., but diethylene glycol, $HOCH_2CH_2OCH_2CH_2OH$, has received the widest acceptance in industry. Hence, it is a substance which does not vaporize too extensively into the gas and yet has a high affinity for water. All of these liquids are expensive and must be conserved if the operation is to be economical. Figure 1 is a flow diagram of the continuous process, showing the essential circulation. Since gasoline is slightly soluble in the glycol

solution, some provisions must be made for collecting the condensate extracted upon regeneration of the solution.

The Dew Point Depression

The measure of dehydration which has been accepted in the natural gas industry is the dew-point depression, or the difference between the dew point of the humid gas entering and the dew point of the dried gas leaving the plant. It is recognized that many factors affect dew-point depression in the operation of the diethylene glycol system. The chief factors which have bearing upon this criterion are as follows:

1. *Concentration of water in dehydrating medium.* The higher the water content of the diethylene glycol solution, the lower the dew point depression which is possible. Conversely, the higher the glycol concentration, the higher the vaporization losses of this expensive material.

2. *Temperature of gas and solution in contactor.* At sufficiently high temperatures, the dew point of the processed gas can actually be higher upon leaving the contactor than upon entering. Therefore, it is desirable to operate at as low a temperature as is practicable. Some plants have resorted to mechanical refrigeration of the gas and the solution to take advantage of this factor.

3. *Number of actual plates in the contactor.* Other factors remaining the same, the greater the number of contacts between the glycol solution and the gas, the lower will be the water content of the outlet gas. In practice, the optimum number of actual plates per contactor varies from four to six, though some glycol plants have been designed without plates.

4. *Efficiency of contact of liquid and vapor.* Experimental tests which have been conducted in the field as well as the laboratory indicate a wide variation in the ability of a plate to mix perfectly the liquid and gas. The overall ratio of the theoretical to actual trays has been found to vary from 0.4 to 0.9 as a rule. The conventional bubble plate is approximately 0.6 as effective as a perfect plate. Channeling of solution across the plate can markedly decrease the efficiency of contact. Consequently, the greater the efficiency of contact, the fewer the actual plates required; or conversely, for the same number of plates, the greater the dew-point depression.

5. *Rate of circulation of glycol solution.* As a general rule the greater the quantity of diethylene glycol circulated, the fewer the number of actual plates required to effect a fixed dew-point depression. With the same number of plates, as is the case of a plant in operation, higher circulation rates will give greater dew-point depressions. Figure 4 presents graphically the effect of the actual number of plates and glycol composition on the quantity of solution required to give a dew-point depression of 29° F.

6. *Inlet-gas dew point.* Holding the same glycol composition, system temperature, circulation rate, etc., the effect of inlet-gas dew point on the dew-point depression is nil. Over short temperature ranges, the dehydrated-gas dew point increases and decreases directly with the inlet-gas dew point.

TABLE 1
Vapor Liquid Equilibrium Data*

Percent Water by Weight Glycol Solution	Vapor Pressure of Sol'n. mm of Hg.	Mols. Water per Mol. Glycol in Solution	Equilibrium Mols. Water per Mol. of Gas
1.0	0.43	0.0595	0.0000388
2.0	1.10	0.1202	0.0000992
3.0	2.10	0.1822	0.000189
3.8	2.60	0.2327	0.000235
5.0	3.40	0.3100	0.000307
10.0	5.90	0.6544	0.000532
15.0	8.20	1.0394	0.000740
20.0	9.6	1.4725	0.000866

*Vapor pressures taken from Figure 2.

Graphical Calculations of Design and Operation

As an operating problem, it is desired to determine the optimum glycol circulation rate for a contactor composed of four actual bubble trays of a 60-percent efficiency.

Operating Conditions

Dew point of inlet gas	54° F.
Desired dew point of outlet gas	25° F.
Pressure, psi, gauge	200
Barometer	14.0
System temperature	68° F.
Specific gravity of glycol solution	1.117
Percent diethylene glycol by weight	95

The solution of the problem is obtained by determining graphically the number of actual plates required for several assumed glycol-circulation rates. The graphical solution is based upon a material balance for water entering and leaving the absorber during steady-flow conditions. The mathematical relationship between the liquid and vapor composi-

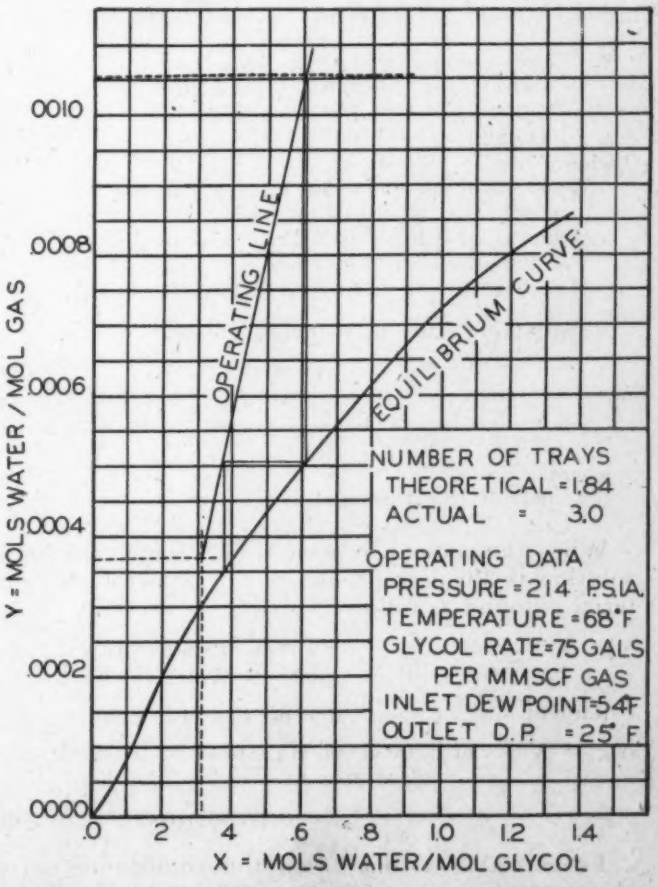

FIGURE 3—Absorption diagram for diethylene glycol extraction of water vapor from natural gas.

tion at any point in the system is given by the equation as follows:

$$G(Y_1 - Y_2) = L(X_1 - X_2)$$

where:

G = Mols of dry gas processed per unit time
Y_1 = Mols of water per mol of gas entering system
Y_2 = Mols of water per mol of gas leaving system
L = Mols of glycol circulated per unit time
X_1 = Mols of water per mol of glycol leaving system
X_2 = Mols of water per mol of glycol entering system

Neglecting the glycol which is lost from the system by vaporization and the natural gas components which are absorbed in the glycol solution, the ratio of L/G gives the slope of a straight line defining the vapor composition, Y, as a function of the liquid composition, X. This straight line is known as the "operating line."[1]

Calculations of Slope and Gas Composition

By assuming a glycol circulation rate of 75 gallons per million standard cubic feet of gas, one is able to establish the slope of this line.

$L/G = (75)(1.117)(8.33)(0.95)/106 + 1{,}000{,}000/379 =$ 0.00237 Mols glycol/Mol gas

where:

Specific gravity of glycol solution = 1.117
Weight of one gallon of water at 60° F. = 8.33
Fraction of glycol in solution = 0.95
Molecular weight of glycol = 106 lbs./lb. mol.
Number of standard cubic feet of gas processed/75 gals. glycol = 1,000,000
Number of standard cubic feet of gas per lb. mol. (14.7 psi abs. and 60° F.) = 379

From a dew point chart,[2] the water content of the natural gas of a given dew point can be found.

Y_1 = Mols of water/mol of gas entering = $(50)/(18) \div (1{,}000{,}000)/379 = 0.00105$
Y_2 = Mols of water/mol of gas leaving = $(17.5)/(18) \div (1{,}000{,}000)/379 = 0.000369$

where:

Water vapor content of 54° F. dew point gas at 200 psi g. = 50.0 lbs./mmscf
Water vapor content of 25° F. dew point gas at 200 psi g. = 17.5 lbs./mmscf
Molecular weight of water = 18.0 lbs./lb. mol

Molal ratio of water to diethylene glycol =

$$\frac{\frac{\%\text{ water}}{18}}{\frac{100 - \%\text{ water}}{106}} = \frac{(\%\text{ water})\ \frac{106}{18}}{(100 - \%\text{ water})}$$

where:

Pounds of glycol per mol of glycol = 106

When the percent by weight of water in the liquid solution is 1.0 percent, the molal ratio for this material is found as follows:

$$X = \frac{\text{Mols water}}{\text{Mol glycol}} = \frac{\%\text{ Water } (5.89)}{100 - \%\text{ Water}} = 0.0595$$

Ratio of Mols of water vapor per mol of dry gas =

$$Y_{eq} = \frac{(\text{Vapor pressure in mm Hg.})(14.7)}{(760)(214)} = (0.0000902)(VP)$$

$$= (0.0000902)(0.43) = 3.88 \times 10^{-5}$$

From Table 1, one plots the equilibrium curve shown on Figure 3. Also, from Table 1, one obtains the ordinate of the anchor point of the operating line.

TABLE 2

Circulation Rate Gallons of Glycol Solution per Million Cu. Ft. of Gas	Actual Number of Plates Required for Absorption Operation
30	6.38
35	5.5
50	3.8
60	3.33
75	3.0
100	2.68
150	2.28

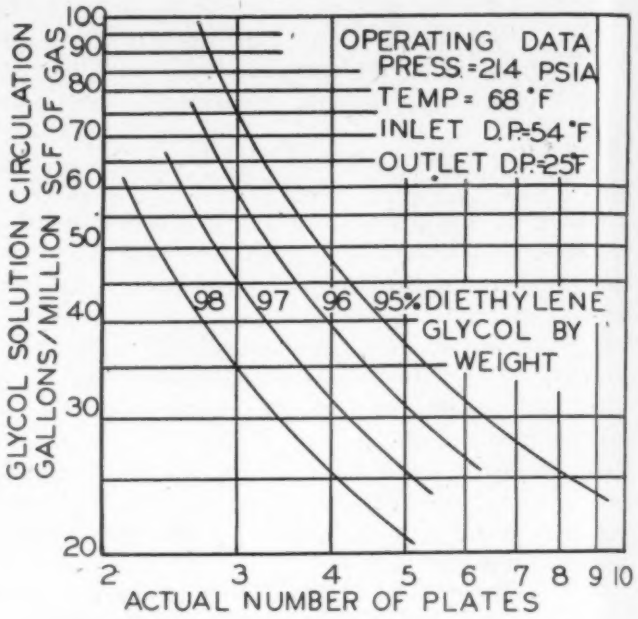

FIGURE 4—Circulation diagram for a 29 F.-dew-point depression.

The abscissa has been calculated as Y_2. Through this point, the operating line of slope $\frac{L}{G}$ is drawn until it intersects Y_1. Through this second point of intersection a vertical line is dropped to the equilibrium curve. Reading to the left, the point of intersection of the operating line gives the first theoretical plate. The plates are stepped off in this way until the water-vapor content of the outlet gas is reached. The number of steps and fraction of a step gives the number of theoretical trays required to carry out the given dew point depression.

$$\text{Actual Number of Trays (assuming 60\% efficiency)} = \frac{\text{Theoretical Trays}}{0.60} = \frac{1.84}{0.60} = 3.0$$

By repeating the above calculations and assuming different circulation rates, one gets values as shown in Table 2, which are plotted for Figure 4.

A smooth curve is drawn through the plotted points. Reading up from four actual plates, one finds the necessary circulation rate to be 48 gallons of 95-percent glycol solution required per million standard cubic feet of gas processed to give the desired dew point depression of 29° F.

Similar calculations and plots can be made to determine the quantitative effect of the various factors mentioned under the discussion of dew-point depression.

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[2] Russell, Thompson, Vance and Huntington, "The Experimental Determinations of Water Vapor Content of a Natural Gas up to 2000 Pounds Pressure," AIME Technical Publication No. 1792, Petroleum Technology, January, 1945.

Application of Unit Operations to

Fractionation and Other Vaporization Processes

PART 15

Transportation and Storage of Crude Oil and Crude-Natural Gasoline Blends

R. L. HUNTINGTON, University of Oklahoma

IT HAS been found that the blending of small percentages of stabilized natural gasoline with crude oil offers several economic advantages in transportation. There are, however, certain unfavorable factors which arise from this blending practice such as increased vaporization losses in storage, and fire and explosion hazards in cleaning out tank bottoms.

The first advantage recognized from pipe-line transportation of crude oil-natural gasoline blends was the saving in freight. In the early twenties heavy outage losses were experienced in the tank-car shipment of unstabilized gasoline. By blending from 1 to 2 percent of this "wild" gasoline with crude oil, vaporization losses were reduced materially below those suffered through rail transportation.

Reduction in the viscosity of the crude oil is another factor in favor of blending. This change in the physical property of the liquid brings about a saving in horsepower required to pump.

Blending operations are also found to be desirable for some crudes high in paraffin content. The natural gasoline acts as a solvent under certain conditions thereby lessening the tendency for wax to coat the inside of the pipe line. The alternative of maintaining the oil at a temperature above the pour point is out of the question for long pipe lines in cold weather. One company increased its crude oil deliveries 50 percent by blending natural gasoline (10 percent by volume) with crude oil in winter. This crude has a pour point to 55° F., due to its high wax content. Evaporation losses were not excessive, as much smaller percentages of gasoline were required in summer, to effect the same delivery capacity for the pipe line.

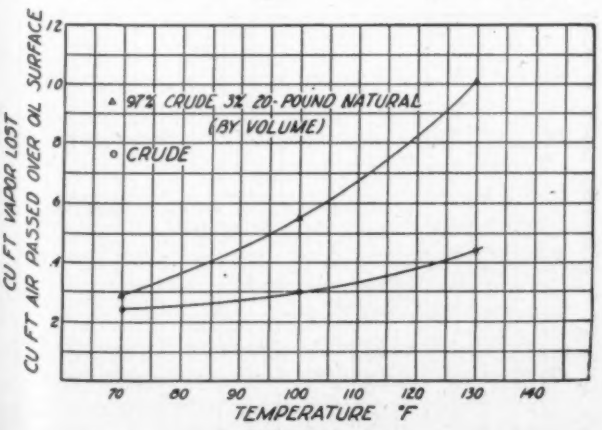

FIGURE 2

Air-vaporization tests. Air flow over crude and blend in five-gallon bottle. Air mass velocity over crude oil surface = .0675 pounds per hour per square foot.

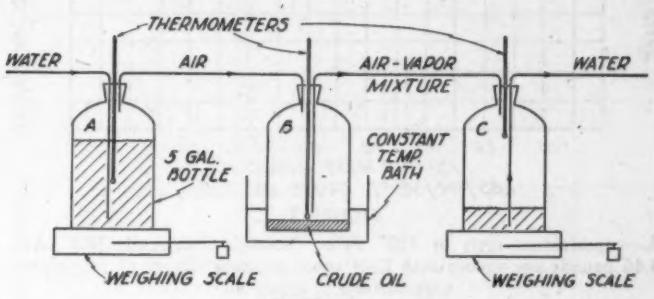

FIGURE 1

Experimental apparatus used in air-vaporization tests on Seminole crude and crude-gasoline blends.

A comparison of the losses in storage tanks is difficult to make due to the frequency of transfers. Laboratory tests were therefore made on a blend from a representative field in Oklahoma in order to determine the relative vaporization losses. A blend was chosen consisting of 3 percent by volume of (26 vapor pressure at 100° F.) natural gasoline and 97 percent 38.8° API crude oil. True-boiling-point fractionations were made at low temperatures on the crude oil, 26 natural gasoline and the 3 percent natural-97 percent crude blend. The tests are as follows:

	Crude Oil (Mol %)	Blend (Mol %)	(26-70) Natural Gasoline (Mol %)
Propane	.38	.55	.....
Isobutane	.64	5.17	2.44
Normal Butane	3.23		37.50
Isopentane	1.37	6.26	28.90
Normal Pentane	3.73		
Hexanes	7.78	8.10	16.12
Heptanes	7.51	9.18	15.04 (C_7+)
Octanes +	75.36	70.74	.....
Mol Wt. of Octanes +	192	.....	.....
A.P.I. of Octanes +	33.3	.....	.....

	Reid Vapor Pressures Lbs. per Sq. In. Absolute			
	A.P.I. at 60° F.	70° F.	100° F.	130° F.
Crude	38.7	3.4	6.4	10.9
Blend {3% Natural Gasoline / 97% Crude	39.7	3.8	7.3	12.1
26-70 Natural Gasoline	88.1	15.8	27.4	43.7

In Figure 1 a diagrammatic sketch shows the small-scale apparatus which was used to duplicate, in a measure, conditions existing in a storage tank subject to air infiltration at night and air-vapor exhalation by day. These tests were made under steady state conditions at several temperatures and at different rates of air flow, in order to determine the approach toward equilibrium conditions. In Figure 2, the results of six of the air vaporization tests are given. It will be observed that at 70° F., the relative volatility of the blend to that of the crude is 1.23. At 100° F., it is 1.83 and at 130° F., 2.27. Each of these six tests was made over a period of one hour at an air

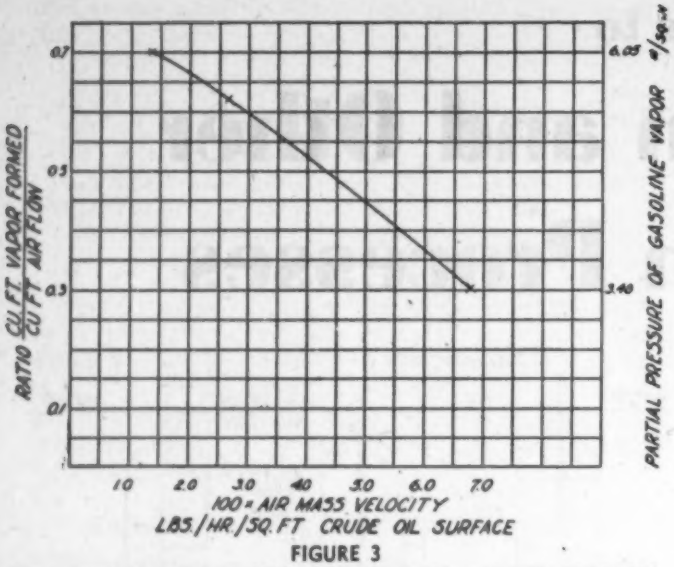
RATIO CU. FT. VAPOR FORMED / CU. FT. AIR FLOW
PARTIAL PRESSURE OF GASOLINE VAPOR
100 = AIR MASS VELOCITY
LBS./HR./SQ. FT. CRUDE OIL SURFACE

FIGURE 3

Air-vaporization tests at 100° F. on Seminole crude oil, 38.8° API, 3.46 pounds per square inch Reid vapor pressure. Effect of air velocity over surface of crude oil.

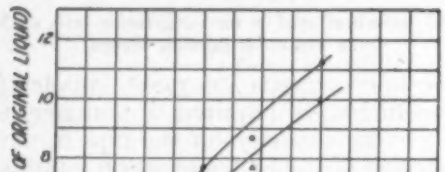

FIGURE 5

Laboratory weathering tests in 1000 cc. cylinders.

mass velocity of .0675 pounds per hour per square foot of crude oil surface.

In Figure 3 is shown the effect of variable air velocities on the amount of vapor picked.

The lower the mass velocity of the air, the better is the approach toward equilibrium conditions. From Figure 3, it is to be observed that the gasoline vapor picked up by the air is three and a half times as much

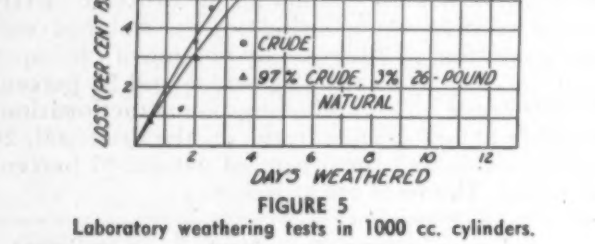

FIGURE 6

Weathering tests in 1000 cc. cylinders.

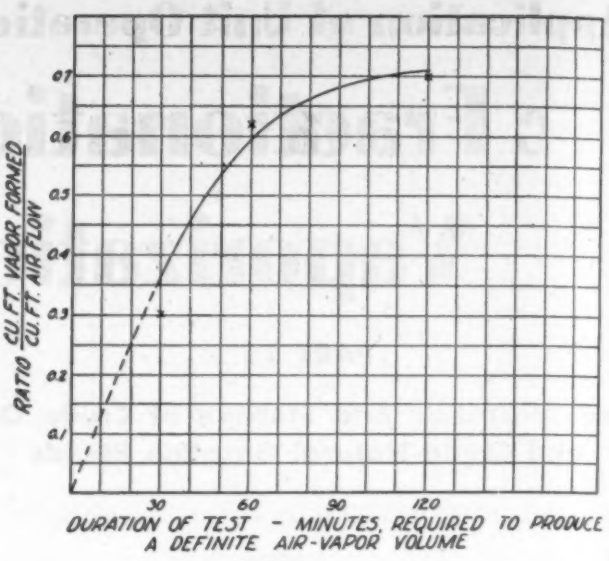

FIGURE 4

Air-vaporization tests at 100° F. on Seminole crude oil, 38.8° API, 3.46 pounds per square inch Reid vapor pressure. Effect of air velocity over surface of crude oil (from same experimental results as shown in Figure 3).

at a mass velocity of 1.3 pounds per square foot per hour as it is at 6.75 pounds mass velocity. For some unexplainable cause the partial pressure of the gasoline vapor reached a maximum of 6.05 pounds per square inch. This value was obtained as follows:

The ratio of gasoline vapor volume to that of air is 0.7 to 1.0 for the highest ratio. Since the partial pressures are proportional to the respective volumes of each component in the mixture, the partial pressure of the gasoline vapor would be

$$(.7/.7 + 1.0) \times 14.7 = 6.05 \text{ lbs.}$$

The same experimental results as shown in Figure 3 are presented differently in Figure 4.

One sample each of the crude and the blend was placed in a graduated cylinder in a room over a nine-day period. The results of this test are shown in Figures 5 to 8 inclusive. It will be observed that the relative loss of gasoline from the blend to that of the crude oil over a two-day period was 1.24; five-day period 1.15; and for nine days 1.125. Over this nine-day period API gravity of the gasoline lost from the crude oil was 74.4° API and from the blend 81.8°.

For every degree loss in API gravity of the crude oil, there is an approximate shrinkage of 2½ percent by volume, or slightly over 1.05 gallons of gasoline lost per barrel. Since the molecular weight of this

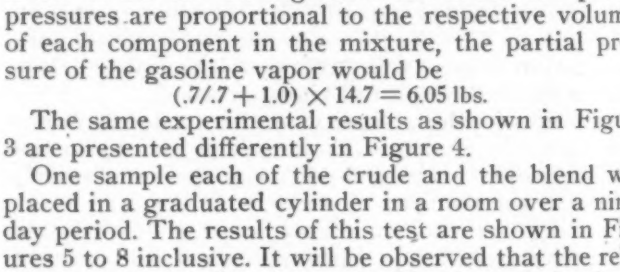

FIGURE 7

Weathering tests in 1000 cc. cylinders.

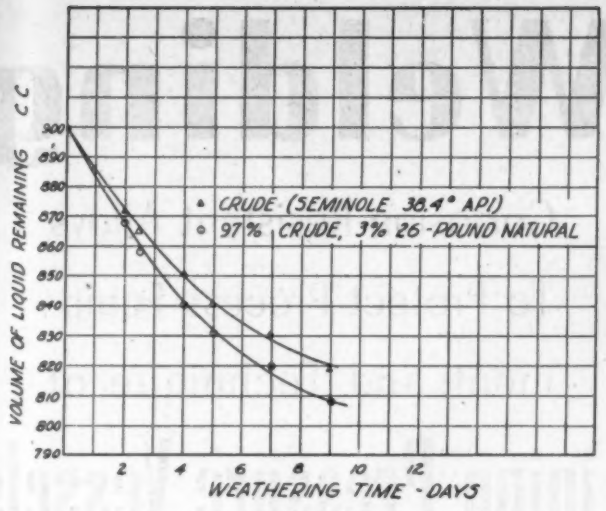

FIGURE 8

Weathering tests in 1000 cc. cylinders.

vapor is approximately 72, or that of pentane, there would be (1.05 × 27.7) or 29 cubic feet of vapor evolved per barrel of crude oil if it was being lowered in gravity one degree. In terms of large quantities, such as 1000 barrels of crude oil, there would be 29,000 cubic feet of vapor evolved during this one-degree drop in gravity; and this vapor in turn could form as much as 2,240,000 standard cubic feet of explosive mixture in air. This latter calculation on the explosive mixture is based on data published by H. F. Coward and G. W. Jones in Bulletin 279, United States Bureau of Mines, on the "Limits of Inflammability of Gases and Vapors." The amount of vaporization from a tank would be a function of the physical properties of the oil, its temperature, and the rate of air circulation over the surface of the oil.

Results for weathering tests over a 58-day period are shown in Figure 9. After 15 days of weathering the rate of evaporation loss is practically the same for both the crude and the blend.

It seems logical that the bottom sediment from the blend of gasoline and crude oil would be more volatile than the settling from crude oil alone. This conclusion is based on the fact that crude oils recovered from bottom sediments are as a rule almost as high in API gravity as the original crudes themselves.

The author has received information from a crude-oil reclaiming company which treated tank bottoms near Dublin, Indiana. It was observed on this tank farm that storage tank bottoms, settling from Seminole crude, were far less volatile than bottom sediment from the 3 percent gasoline-crude oil blend. An explosion occurred during the cleaning out of one of the tank bottoms containing the blend, as a result of the ignition of vapor at a distance much farther from the tank than would usually be considered hazardous.

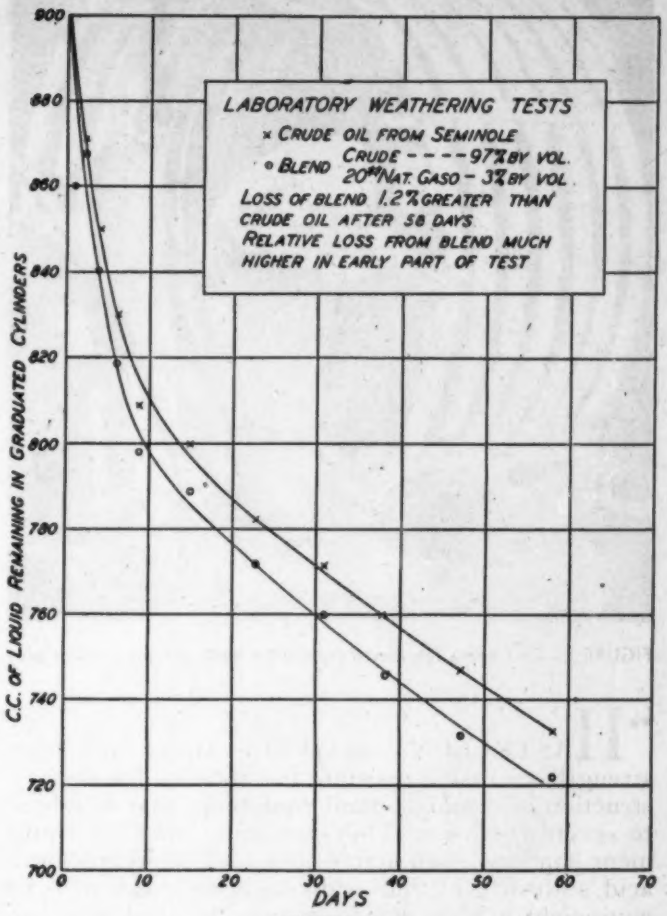

FIGURE 9

Results of a weathering test over a two-month period.

The experimental laboratory data on the weathering of bottom sediments originating from the Seminole crude and blend, as presented in Figure 10, show that the settling from the blend lost 3.8 percent more by weight over a 92-day period than the sediment from the crude.

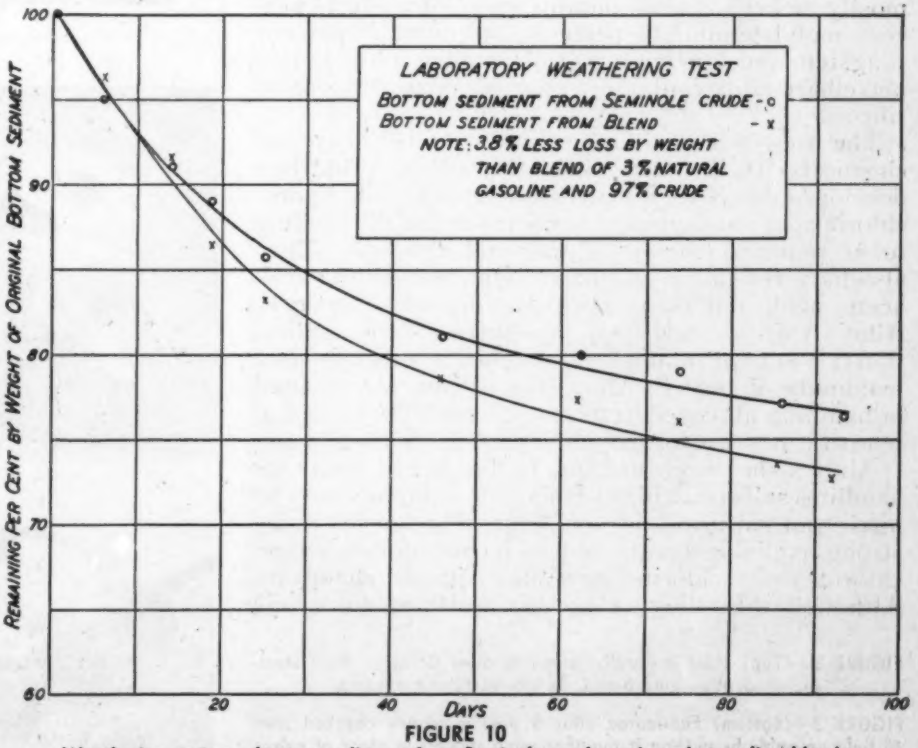

FIGURE 10

Weathering tests on bottom sediment from Seminole crude and crude-gasoline blends.

Welding

Corrosion-Resistant Alloys To Protect Process Equipment, and Technique of

Lining Pressure Vessels

J. A. GALLAHER
Haynes Stellite Company, Chicago, Illinois

FIGURE 1—Coil being fabricated from short cast sections of alloy pipe.

THE author does not propose to pass judgment on the different welding procedures employed for installing liners for corrosion protection in process vessels. Instead, he discusses the different practices that have been used, with the thought that plant designers and fabricators may be aided in decision as to which type seems best for the equipment involved.

In like manner this discussion deals with application and welding of one group of acid- and corrosion-resistant alloys. Obviously, the mechanics of installing the linings would apply to any metal used for such purpose, using appropriate materials and technique for the welding.

Material for this article is taken from a paper presented by the author before the Chicago Section of the American Welding Society.

"HASTELLOY" nickel-base alloys are high-strength, corrosion-resistant metals used for the construction of chemical-plant equipment that is subject to severe corrosion. They are being used for equipment handling such active chemicals as hydrochloric acid, sulfuric acid, and oxidizing agents, as well as for equipment used in many organic chemical processes that employ corrosive catalysts, like aluminum chloride.

As indicated in Table 1, Hastelloy alloys A and B contain molybdenum and iron in a nickel base; alloy A has approximately 20 percent molybdenum and 20 percent iron, and alloy B contains approximately 30 percent molybdenum and only 5 percent iron. Hastelloy alloy C, the most complex of the four, is mostly nickel but also contains approximately 15 percent molybdenum, 15 percent chromium, 5 percent tungsten, and 5 percent iron. Hastelloy alloy D is a nickelbase alloy containing approximately 10 percent silicon.

The uses of these alloys are not confined to special chemicals. To illustrate, Hastelloy alloys A and B—developed primarily for corrosion resistance to hydrochloric acid—are giving excellent service in handling other reducing chemicals and acid chlorides. They also have resistance to sulfuric acid, phosphoric acid, acetic acid, and many corrosive organic chemicals. Alloy A is for relatively low-temperature applications; it is used to handle hydrochloric acid only to a maximum of 160° F. Alloy B, however, can be used in handling all concentrations of hydrochloric acid at temperatures up to and including the boiling point.

Alloy C has been used for a number of years for handling sulfuric acid, hydrochloric acid, mixtures of nitric and sulfuric acid, and especially for the many strong oxidizing agents such as ferric chloride, cupric chloride, wet chlorine gas, and organic chemicals. Although this alloy is not so resistant to strong

FIGURE 2—(Top) Steel is readily joined to alloy C, as in these steel-jacketed alloy pipe bends, by oxy-acetylene welding.

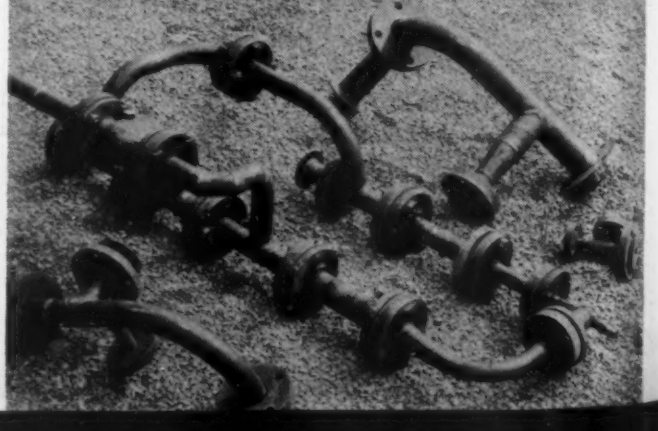

FIGURE 3—(Bottom) Fabricated alloy B pipe is readily checked prior to field assembly by putting it together using spacers in place of valves.

hydrochloric acid as the A and B alloys, it is more resistant to weak aerated solutions.

Alloy D is used chiefly for handling hot sulfuric acid, but it has good resistance to phosphoric, cold hydrochloric, and many other acids.

All four of these alloys are supplied in a variety of forms. Alloys A and B are supplied in the form of hot-rolled sheet and plate; forgings; welded tubing; welding rod (alloy B only); wire; and castings such as cast pipe, fittings, and valve and pump parts. Because these two alloys can be hot-rolled and forged, they are fabricated into many kinds of equipment.

Alloy C is available in hot-rolled sheet and plate but cannot be supplied in forgings or hot-rolled bars. Alloy D is supplied in the form of castings only.

All of these alloys can be welded readily, and welding shops experienced in welding materials such as Monel, stainless steel, nickel, and other metals, usually can adopt their practices to welding Hastelloy alloys.

For many years, practically all welding of these alloys was done by the oxy-acetylene process. With the proper procedure, this process gives adequate corrosion resistance in the weld. The chief precautions that have to be taken in oxy-acetylene welding all four of these alloys are avoid—carbon pickup and overheating. Carbon pickup can be minimized by using a neutral flame, taking care to avoid an excess of acetylene. Carbon pickup is particularly detrimental to alloy C, because this alloy contains chromium and thus picks up carbon much more readily, increasing the corrosion rate. Because of the physical characteristics of alloy D, the oxy-acetylene process is the

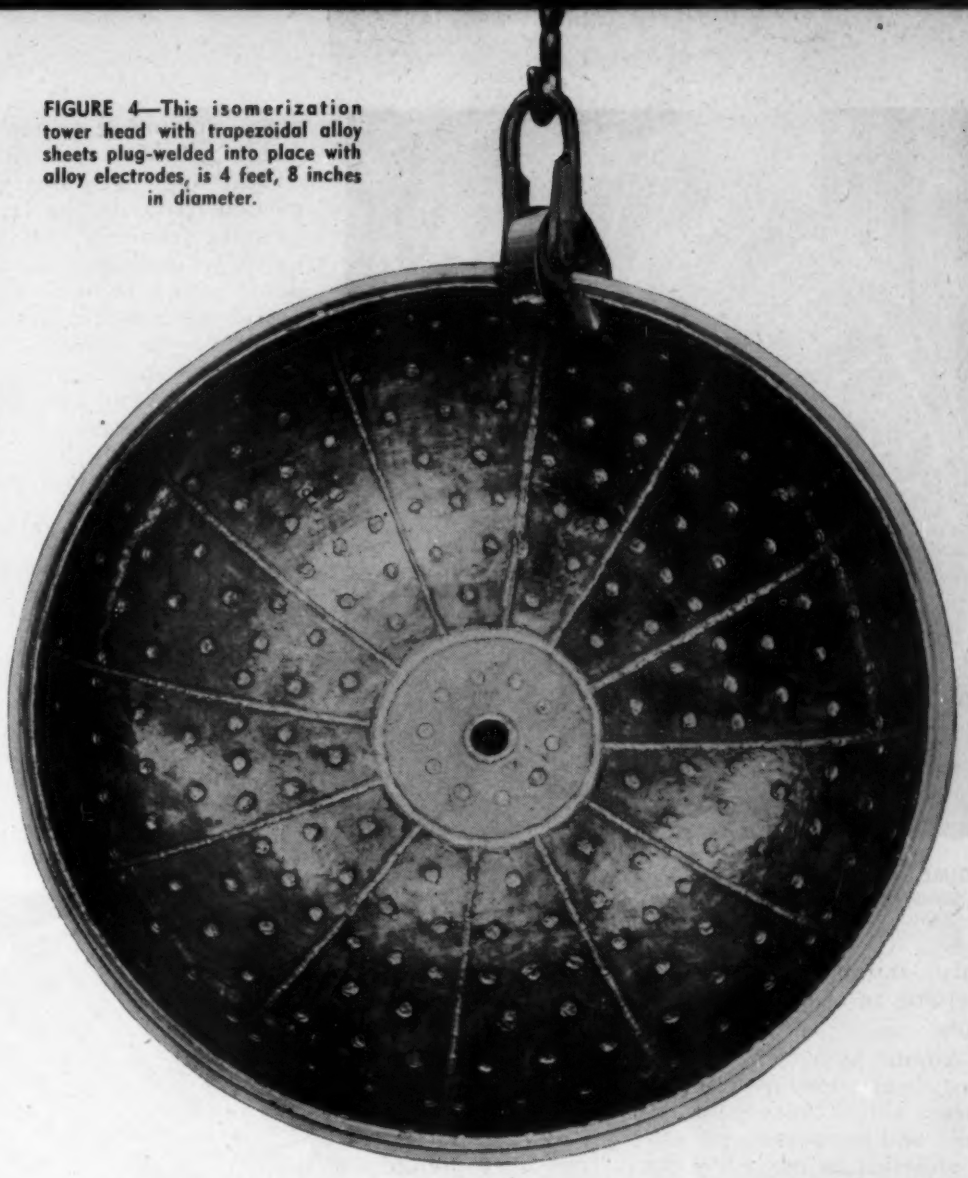

FIGURE 4—This isomerization tower head with trapezoidal alloy sheets plug-welded into place with alloy electrodes, is 4 feet, 8 inches in diameter.

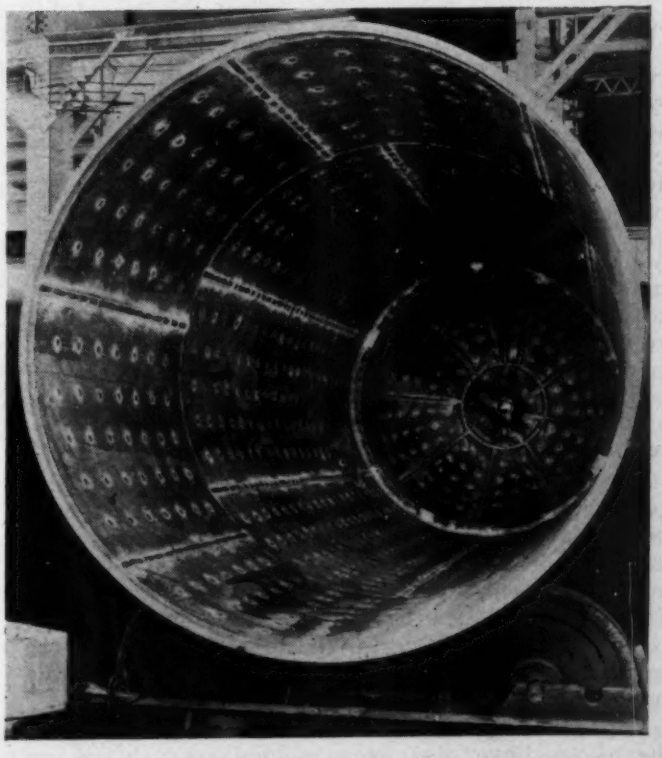

FIGURE 5—This lower half of one of the early isomerization vessels lined with plug-welding, is 36 feet long and 6 feet in diameter.

TABLE 1
Principal Welding Features of "Hastelloy" Alloys

ALLOY	Composition, Percent	Weldable Forms	Welding Process	Principal Use	Average Rockwell Hardness
A	Ni Mo-20 Fe-20	Cast	O-A	HCl	B-92
		Wrought or Rolled	1)M-A 2)O-A		B-96
B	Ni Mo.-30 Fe-5	Cast	O-A	Hot HCl	B-95
		Wrought or Rolled	1)M-A 2)O-A		B-98
C	Ni Mo-15 Cr-15 W-5 Fe-5	Cast	1)O-A 2)M-A	Cl_2, (O)	B-93
		Rolled	1)M-A		B-91
D	Ni Si-10 Cu-1 Al-1	Cast	O-A	H_2SO_4	C-52

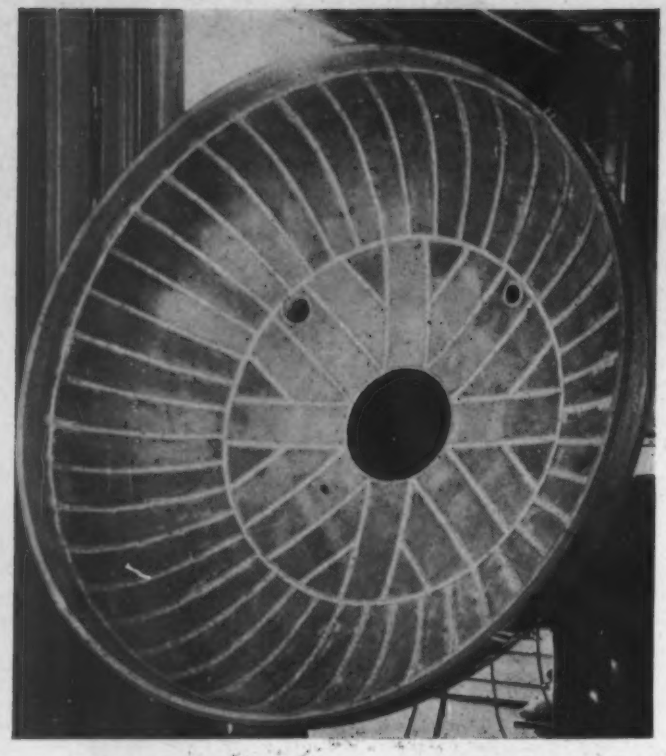

FIGURE 6—A strip-welded tower head, lined with narrow alloy sheets.

only suitable method for welding in ordinary production.

Atomic-hydrogen welding has been employed with these alloys very successfully and in at least one way is superior to oxy-acetylene welding; there is no possibility of carbon pickup in the weld. The principal difficulty with the atomic-hydrogen process for these alloys, however, is controlling the heat, to prevent overheating the weld metal and the areas adjacent to the weld. If the metal is overheated, a certain amount of corrosion resistance is lost, particularly in the sheet adjacent to the weld. With proper control, however, an operator can produce satisfactory results by working rapidly along the line of the weld.

The most satisfactory all-around welding process for sheet and plate alloys A, B, and C, is the metallic-arc process. Electrodes of the same alloys are used except with alloy A, for which alloy B electrodes are used. Problems of electrode coatings and welding techniques have been solved to such an extent with alloys B and C that coated rods that will produce strong, corrosion-resistant welds are now available in both these alloys.

It might be mentioned in passing that all four of the alloys have also been welded recently on an experimental basis by both the "Heliarc" and "Union-melt" welding processes. The work on these types of welding, however, is still in the development stage, and although preliminary results look very promising, particularly with the Heliarc method, it is too early to state definitely that this type of welding will be entirely satisfactory, and further work will have to be done before recommendations can be made as to where this welding process is best adapted.

Welding with such gases as propane and hydrogen has also been done on a limited scale, with but little advantage, if any, over the oxy-acetylene or atomic-hydrogen processes. With the straight oxy-hydrogen process, some difficulty has been encountered in getting sufficient heat to make a satisfactory joint.

Oxy-Acetylene Welding A, B, and C Castings

The principal precaution required in oxy-acetylene welding these alloys is to prevent overheating and to avoid any pickup of carbon.

Satisfactory oxy-acetylene welds have been regularly obtained on cast pipe and castings of all four alloys. An alloy C coil, as illustrated in Figure 1, is thus fabricated of short cast sections. A neutral flame should, of course, be maintained. When large castings are to be welded, it is necessary to preheat to a dull red heat so as to avoid possible cracking difficulties. On small castings of alloys A, B, and C, or when making butt welds in pipe of these three alloys, preheating with the flame generally will bring the material up to a sufficient temperature for welding. The 2-inch flanged bends of alloy C illustrated in Figure 2 were thus jacketed with 3½-inch steel pipe.

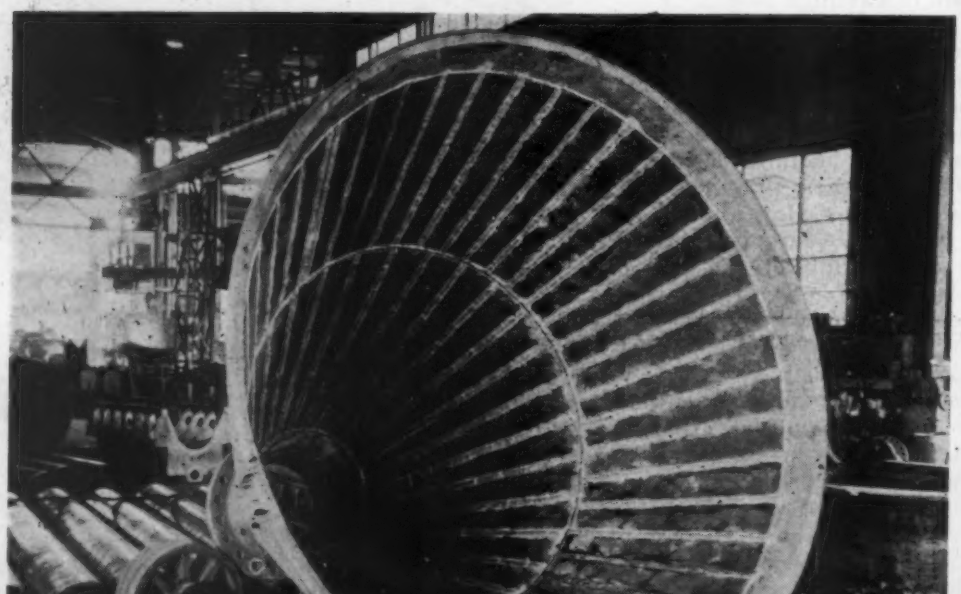

FIGURE 7—For lining the conical bottoms of isomerization towers, alloy strips are applied parallel to the length of the vessel.

Butt-welding pipe of alloys A, B, and C by the oxy-acetylene process can be done without the use of flux, although a special flux supplied by the alloy manufacturer sometimes facilitates the welding

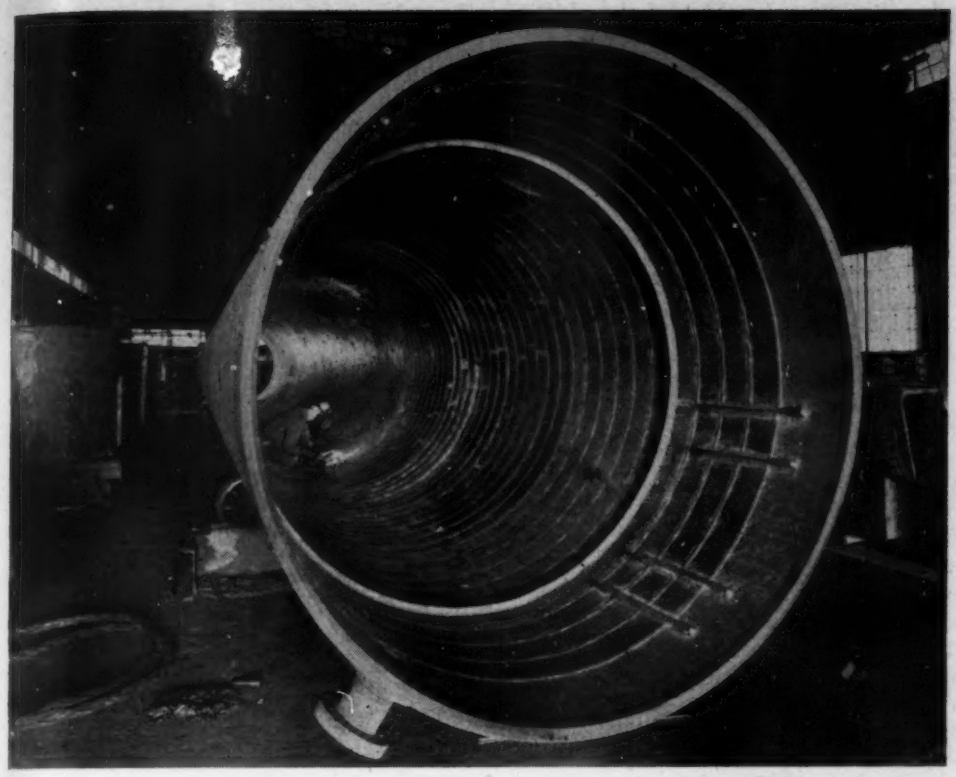

FIGURE 8—Alloy strips are placed circumferentially in the vessel body for lining by strip welding.

operation when used in limited quantities. Many of the ordinary welding fluxes on the market are unsuitable for use, since they may cause a definite loss of corrosion resistance in the weld. Figure 3 shows some typical welded pipe sections spaced out to check size before they are put in chloride service. Iron spacers have been placed where valves will be tied in. This alloy B tubing has all been oxy-acetylene welded.

In welding alloy A, B, or C castings, corrosion resistance is not lost unless an unnecessary amount of heat is applied or unless the casting is held in a critical temperature range over a several-hour period. Normally it is not necessary to fully anneal the cast material after welding, but if a casting for any reason is left in the furnace too long at a red heat, it may be desirable to fully anneal by the treatment described below.

Oxy-Acetylene Welding Alloy D

The welding of alloy D is somewhat different from that for the other alloys; welding D is like welding cast iron. Actually, the physical properties of these two metals are very similar, and their melting points are close together, that of cast iron being approximately 2190° F., and that of Hastelloy D, 2060° F. Molten alloy D, like cast iron, is quite fluid so that a welding operator who knows how to weld cast iron should have little difficulty in following the few set rules which should be applied when welding alloy D.

Preheating, to prevent cracking, is most important. All castings of alloy D should be preheated to a temperature of approximately 1400° F., and arrangements should be made to keep the alloy at an even temperature throughout the welding operation. Small pieces can be welded by preheating locally with the oxy-acetylene flame. Recently, pipe of alloy D up to 3 inches in diameter has been welded by using two oxy-acetylene welding blowpipes, one maintaining the heat while the other one does the welding. Pipe larger than 3 inches in diameter, however, should be welded in a preheating furnace. In welding 6-inch pipe, for instance, it is often found desirable to build the funace around V-blocks so that it surrounds the pipe and extends about 5 inches on either side of the joint. Any kind of a burner—kerosine, gasoline, or gas—can be used so long as the pipe is preheated slowly at first.

The furnace should, for convenience, be arranged so that welding is done at the top. In preheating, the flame should not be applied directly to the castings at first. The heat should be indirect and slow until the castings reach approximately 800° F., at which point they can be heated much faster. When they have reached a temperature of approximately 1400° F., welding can be started. Because the molten alloy

FIGURE 9—For strip-welding the alloy lining to the steel, the strips are first tack welded securely.

is quite fluid and difficult to weld vertically, it is good practice to weld about 2 inches of linear joint at a time, to allow time for the weld metal to solidify, and then weld another two inches. If the operator tries to weld this alloy continuously, as if it were steel, the metal may become too hot, and its high fluidity may cause complete lack of control. It may also become gassy, causing porosity in the weld.

When welding has been completed, the preheating burner should be left on until the casting is evenly heated throughout the welded joint. The burner can then be turned off and the welded part left in the furnace to cool slowly. Small pieces, such as pipe,

which are not welded in a preheating furnace, should be buried in some substance such as lime, sand, or ashes, to keep the air from reaching the weld so that it does not cool too rapidly. If such care is not taken —just as with cast iron—cracking is likely to occur.

Welding A, B, and C Sheet and Plate

For the fabrication, by welding, of refinery reaction vessels, chemical plant autoclaves, heat exchangers, receivers, stills, and tanks made up from sheet and plate of alloys A, B, and C, the metallic-arc, atomic-hydrogen, and oxy-acetylene processes have all been used. From the standpoint of speed, however, the metallic-arc process is preferable. These alloys flow very well under the metallic arc, and form a good-looking weld with a nice cover bead and excellent penetration. In welding with the metallic arc, using reversed polarity on a coated rod, all three alloys flow freely and are likely to be more fluid than under the atomic-hydrogen arc or the acetylene flame.

Weld tension tests made on alloy B have shown that the metallic-arc process gives greater strength than the atomic-hydrogen process. In one example, welds made on this alloy with the atomic-hydrogen process show ultimate strengths of from 91,000 to 97,000 pounds per square inch. With the metallic-arc process, similar welds showed strengths of between 115,000 and 122,000 pounds per square inch. In both series of tests, the specimens broke in the welds, and in the specimens welded by the atomic-hydrogen process the weld metal showed a very fine grain structure. Free-bend tests for elongation of the weld metal showed a maximum of 21 percent elongation on the specimen welded by the atomic-hydrogen process and 22 to 28 percent on the specimen that was metallic-arc welded.

As with steel, beveling is desirable when welding heavy plate of alloys A, B, or C. It is usually preferable to use two fillets, and a double-vee weld is desirable where welding from both sides is possible. If welding can be done from only one side—as in the fabrication of most pipe—a large vee weld should be made with two passes. The first pass with a small rod can fill the bottom of the bevel and obtain the required penetration, and the second pass with a large rod can build up the groove and complete the weld. In making double-pass welds, particular attention must be given to cleaning the flux out of the groove before making the second pass. Peening the welded deposit is not desirable because these materials work harden.

Precipitation occurs in the sheet adjacent to the weld if the metal is held for any length of time within a critical temperature range. This is most noticeable in alloy A; alloys B and C being quite stable. The effect is similar to that obtained when welding unstabilized stainless steel. In arc welding Hastelloy alloys, it is recommended that the welding be done rapidly and with as little current as possible. Also, that the arc be choked short and the electrode be worked away from the molten puddle.

If for any reason, the metal in a single-vee weld becomes so fluid that it causes beads to form on the inside of seam welds, it may be desirable to employ copper backing-up strips cut with a small groove that allows weld metal to flow through the joint and form a small reinforcing bead on the inside. This is most likely to occur during welding of material of the lighter gages, say, up to ⅛-inch or 11 B.w.g. thickness. If the chill bar is too thick and gives too much of the chilling effect, it may fail to meet its intended purpose.

In one case a double heat-exchanger was completely fabricated of 16 B.w.g. sheet. Each of these has 206 tubes, and the tubes, sheets, and shell are all of alloy C. They are 10 feet long.

Porosity in the weld metal is generally a result of overheating, but it is not usually a problem if the precautions mentioned are taken. When porosity is encountered after the arc has been started, sticking the rod to heat it before again starting the arc will eliminate this trouble. It is also desirable to use rods dried in a drying oven to eliminate any possible moisture pickup in the coating from atmospheric conditions.

Wrought alloys A, B, and especially C are not so stable as the cast alloys. If the metal alongside the weld is kept in the hardening-temperature range for an appreciable time, cracking troubles may occur. In addition, the hardened area of any of the three alloys may be less corrosion-resistant. To overcome these difficulties it is sometimes necessary to give the welded part a full or a stabilizing anneal. If annealing is not feasible, the sheet should be purchased in the stabilized condition. The stabilized sheets are not so ductile as fully annealed sheets, however, and consequently they should be used only when severe forming operations are not required.

Lining With Alloys A and B

The price of these alloys often makes them impractical for use in solid construction of large vessels or high-pressure equipment, but they can be used economically for linings. During the past two years considerable lining work has been done with alloys A and B, and a number of different practices have been developed for installing leak-tight, corrosion-resistant liners. Liners have been installed in vessels as large as 7 feet in diameter and 90 feet high, and operating under pressures as high as 250 pounds per square inch.

In the lining work several procedures have been adapted, all of which have some merits and some limitations. It is not the author's intention to pass judgment on the different welding procedures employed for installing liners. Instead, we prefer to point out all the different practices that have been used, so that fabricators and plant designers can decide for themselves which type seems best for the employment involved.

In the early development work on the installation of liners, no satisfactory arc-welding rod was available, and to overcome this lack quite a lot of work was done with the atomic-hydrogen welding process. The heat of this process often resulted in cracking troubles in the sheet and welds, and the corrosion resistance of the sheet adjacent to the weld was so adversely affected by the heat of the arc, that attention was turned to other processes.

On small lined jobs, the practice was first to weld the liner together. Then it was placed in the steel jacket and welded all around the edges. Although this method was satisfactory for small equipment to be lined with 3/16-inch sheet of alloy B, it is not satisfactory for large vessels.

Liners First Plug-Welded

One of the earliest successful methods used in installing liners was the plug-welding process. Early in the high-octane gasoline program, some liners

were installed in isomerization towers before final assembly. When this was done, the largest sheets within mill limits could be used. Usually, however, linings had to be put in completed steel vessels after they were already in use. Of necessity, the size of the sheets were performed to the curvature of the manway. These sheets varied from 14 to 20 inches in width, depending upon the individual vessel, and all the sheets were preformed to the curvature of the vessel. For plug-welding, some were perforated with slots ¼-inch wide and 1-inch long, and others were drilled with ⅝-inch or ¾-inch diameter holes, the slots or perforations being spaced from 4 to 6 inches apart. The sheets were installed longitudinally and were plug-welded to the steel and fillet-welded around the edges.

Heads were lined, using trapezoidal sheets approximately 4 inches wide on the large base and 1 inch wide on the small base, and varying in length depending upon the size of the head. The head shown in Figure 4 was plug-welded in this manner, using alloy A sheet 0.075-inch thick and alloy B electrodes. It has a diameter of 4 feet, 8 inches and is being used on a vessel 70 feet high. The nozzles were lined with cylinders rolled from sheet, inserted in the nozzle, and welded to the nozzle at each end. The faces of the flanges were covered with an alloy ring either cast or cut from sheet.

Considerable work was done in attempting to line these vessels in position—welding the liners in the field—but without success. While some position welding can be done with these alloys, using the metallic-arc process, welding large installations in position is difficult since the present rods in both alloys B and C are too fluid for satisfactory results. Work is being done on developing a more satisfactory rod for position welding.

Because of this fluidity, tanks or towers already in service must be taken down, so that the welds can be made in a downhand position.

Field welding was just a stopgap—necessary in the early part of the high-octane gasoline program only because steel equipment proved unable to withstand the corrosion of the chemicals involved, and something had to be done quickly. Those concerns that ordered lined vessels direct from the fabricators gave the fabricators a better opportunity to apply their best techniques.

An Eastern concern that had had long experience with the fabrication of these alloys was first called upon to install alloy A linings in the lower sections of new vessels. These sections ran from 15 to 20 feet high. They employed 12 B.w.g. sheet perforated with ⅝-inch diameter holes, 6 inches apart. These sheets were formed as closely as possible to the inner contour of the vessel and held tight against the wall of the vessel with jacks during welding. The welds were made in two passes, the first with flux-coated B electrodes by the metallic-arc process, and the second with bare rod by the atomic-hydrogen process. The initial pass tied the alloy sheets to the steel and the second pass assured a sound deposit on the surface to be exposed to the chemicals. The plug welds, of course, consisted mainly of filling the perforations. For the seam welds, the sheets were spaced 5/16-inch apart and the groove filled.

After this type of welding, each vessel was stress-relieved at between 1100 and 1200° F. Then two test holes were drilled in the steel shell under each alloy sheet, so the liner could be tested by 15 pounds per square inch air pressure. If the lined sections were all right, they were sent to other fabricators, who welded them to the steel upper section, and installed cast nozzles by projecting them directly through the lined steel wall, and welding them to the lining on the inside and to the steel on the outside. Manways were lined with sheet in the same manner as the main vessel.

FIGURE 10—Trapezoidal alloy sheets tack welded in an isomerization vessel head preparatory to strip welding.

Following this, some vessels were lined with 14 B.w.g. alloy A sheet, plug-welded with C rod. This rod had better welding characteristics than the alloy B rod then available and the combination passed the tests for satisfactory corrosion rates.

Alloy B Now Used for Linings

Just about this time, a new coated B rod was developed for metallic-arc welding. This did away with the need for making a cover weld with the atomic-hydrogen arc and resulted in porosity-free welds. At about the same time most of the oil refineries decided to use alloy B sheet in place of alloy A, and it was also found best to have the complete area of the interior of these vessels lined.

Accordingly, over 40 of these large vessels have been built and some of the first have now been in service over two years. Plug-welding has been used by sereral fabricators, and experience in this type of work has shown that a few tricks of the trade are all that is necessary to produce a satisfactory job. The vessel interior shown in Figure 5 was one of the first that was successfully lined with alloy B. It is plug-welded. The section shown, 6 feet in diameter and 36 feet long, is actually the lower half of a tower.

The linings must fit tightly to the steel case. To assure this, the lining is held in position with shoes or supports to prevent the heat of welding from warping the liner away from the base metal. Generally, the sheets are fitted in place and held with shoes. As an

FIGURE 11—A closeup of three-pass strip welds. The first two fillet welds are left about 1/16-inch apart to permit the final bead to penetrate the steel base.

additional precaution, they are tack-welded in place before plug or seam welding. In the early plug-welded construction, some contraction and warpage of the lining was encountered. The warpage caused a few linings to pull loose from their steel backings. This, of course, was due to the large size of sheets employed and the resultant increase in stress.

In one instance, a fabricator corrected this trouble by corrugating the sheet between the longitudinal rows of plug welds to allow sufficient slack to provide for the contraction of the welds. This did not, of course, correct longitudinal shrinkage, but the longitudinal effect could be offset somewhat by starting the welding at the center of the sheet and working toward the ends. The corrugations of the welded sheets were then hammered out with a flatter. This practice resulted in some work-hardening of the material during the flattening operation. Although such work-hardening would be undesirable in the most severe type of corrosive service, it was not great enough in this instance to spoil the linings for the high-octane-gasoline service, and the liners did not draw away from the shells.

Strip-Welding Developed

Strip-welding was the second process employed for installing these big linings. In this process, narrow sheets—varying in widths from 4 to 6 inches—are welded all along the edges directly to the steel shell. With this practice, it is usually easier to hold the liner tight to the steel. Figure 6 shows a head so lined by strip-welding. The principal problem here had to do with the best procedure for making the seam welds. On the plug-welded jobs, most had a two-pass weld on the seam, with the individual sheets placed so that the longer edge was parallel to the height of the vessel, and spaced close together. A number were, however, done in three passes.

For strip-welding the conical bottoms, the strips are applied parallel to the length of the vessel as shown in Figure 7. In the main section of the vessel, however, they were applied with the long dimension running circumferentially. The latter method has been more successful.

In lining up the strips the vertical joints are staggered and the strips must be exactly parallel and follow the true circumferences of the vessel as shown here. As soon as the lining strips are fitted snugly in the vessel, they are tacked in place with a sufficient number of tack-welds to keep the liner tight against the steel while the final weld is being made. Lining the conical or dished heads is done in the same manner, as can be seen in Figure 10 where the trapezoidal plates are shown tacked in the head of the vessel.

In making the strip welds all welding is done in a downhand position. For two-pass strip-welding, the spacing is approximately 3/16- to ¼-inch between the strips. This method puts less heat into the sheet metal adjacent to the weld and also does not require so much welding rod as the three-pass method. On bursting tests of sheet welded to heavy sheet plate, the strength of the two-pass welds was somewhat stronger than that of the three-pass welds, which is probably accounted for by the fact that there is less heat applied to the sheet and therefore less hardening of the weld-affected zone.

For three-pass welding, the strips are spaced ⅜- to 7/16-inch apart, so that a fillet can be made between the edge of each sheet and the base metal, and then a filler pass made over both fillet welds. A closeup of such a weld is shown in Figure 11. The spacing between the bottom of the two original fillet welds should be about 1/16-inch to permit the final fill-in weld metal to fuse to the steel base metal. The fill-in weld is, of course, made only after the adjacent fillet welds have been thoroughly cleaned and checked for defects, such as porosity, lack of fusion, or liner cracks.

Test Procedures Point Way to Improved Technique

In both plug- and strip-welding, porosity and cracks in the welds occasionally caused difficulty. Testing for leaks also gave some difficulty, especially when they occurred between the liner and the steel, since it was frequently possible to check for leaks on the lined sections with air pressures as low as 15 to 30 pounds per square inch. This low air pressure would not reveal leaks that might occur if the equipment were subjected to 500 to 750 pounds per square inch hydrostatic pressure. A more sensitive test has thus been developed wherein hydrogen chloride gas

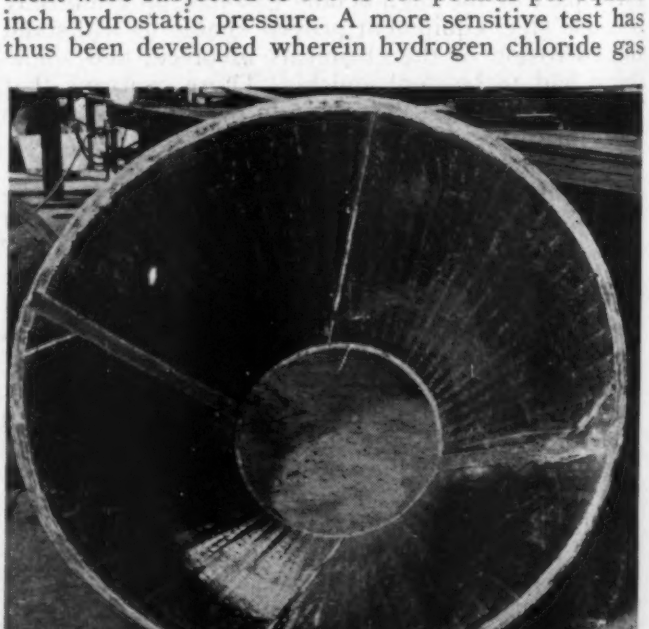

FIGURE 12—The third method of lining—resistance welding—has been applied to this conical tower bottom.

is pumped under 5 to 10 pounds per square inch pressure between the liner and the steel. The inside of the vessel is then swabbed with ammonia, which produces a white cloud at the point of leakage. This test seems to be much more sensitive than the usual air and soapsuds test.

As a result of the hydrogen chloride-ammonia test and the high hydrostatic pressure tests, a number of advantageous precautions were discovered for the seam-welding procedures for alloy B rod used on the edges of sheets applied by both the plug and strip methods. It was again emphasized that the steel should be thoroughly cleaned and the strips have to be held very tightly against it, not only to produce a tight job, but also to dissipate the heat from welding more rapidly. It was found that a short arc was best for producing the lowest possible heat. In fact, a current of only 90 amp. at 25 volts should be used with the 3/32-inch diameter rod, and 120 amp. at 27 volts is sufficient for the ⅛-inch rod. To minimize the heat further, the rod or electrode must be directed almost entirely onto the steel plate and only the edge of the arc should burn into the alloy sheet or strip.

Development work on the third method of lining vessels—with resistance welding—has now progressed to such a point that alloy A is being applied to steel vessels in much the same way as stainless steel is used for lining. Figure 12 and Figure 13 show a resistance-welded bottom cone and a 70-foot vessel completely lined with alloy A by this process. The resistance-welding process now produces very satisfactory linings of alloy A even in such big units as that shown in Figure 13.

Little has been said in this discussion about lining vessels with alloy C, but such work as has been done with this alloy would indicate that it can probably be handled as readily as the other two alloys, and by more or less the same techniques. Increased experience in lining vessels lined with alloy C will certainly iron out any difficulties.

So much experience has been gained in handling Hastelloy alloys in the past two years that the fabricators working with them now have their techniques well developed.

Welded Linings Applied to Valves

Although sheet has been used for lining many large pieces of equipment, welded facings are being used for smaller parts, such as valves. Many hundreds of valves have been salvaged since the start of the war for one particular service requiring an alloy resistant to hydrochloric acid and aluminum chloride. If care is taken to get a clean surface on the steel valves, the port, throat, seat, and plug can all be coated with alloy C or alloy B, using either the oxy-acetylene or the metallic-arc process. Dependent upon the type of steel being employed for the base metal, preheating to from 600 to 1200° F. is necessary, and the parts being coated should be kept at temperature all during the welding period. Of course, on the larger valves maintaining an even temperature in the neighborhood of 1000° F., is essential to avoid cracking the deposit. Proper jigs are also advisable so that all welding can be done in the downhand position. After coating, the parts are cooled in still air. Valve parts thus coated have demonstrated excellent economies in service.

Since full corrosion resistance is developed after welding only by heat-treatment, a word should be said about the heat treatments for these alloys. Heat-treatment is not necessary, of course, when the equipment is to be exposed only to mild forms of corrosion. But where corrosion is a particular problem—and it is for that sort of service that Hastelloy alloys are especially efficient—heat-treatment is usually necessary even if the equipment is large. An example of this is the liner for a 1200-gallon autoclave which was welded of ¼-inch plate and then fully annealed.

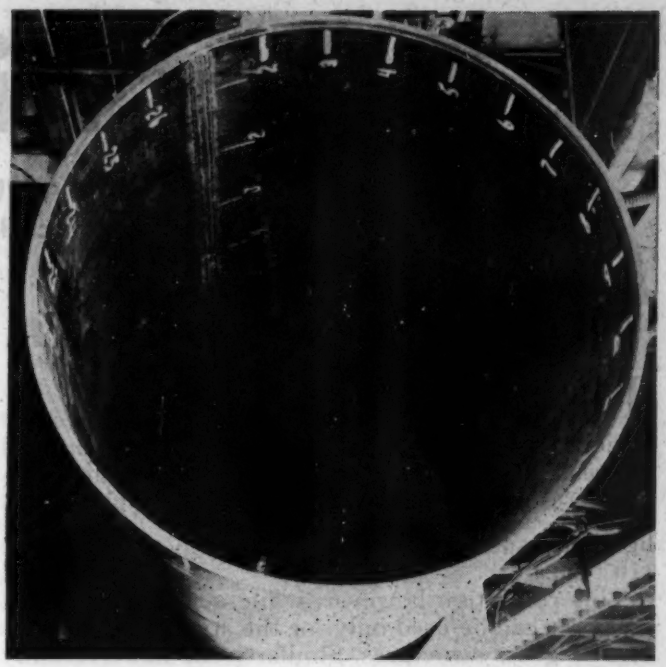

FIGURE 13—This 70-foot isomerization vessel has been lined with alloy by the resistance-welding process.

Only two of the standard heat-treatments will be mentioned. They are called the "full anneal" and the "stabilizing anneal." All alloy A, B, and C sheet and plate is furnished in the fully annealed state unless otherwise specified. This anneal produces softness, toughness, machinability, and high corrosion resistance. On alloys A and B a "full anneal" consists of holding at a temperature of 2100 to 2150° F. for 20 to 90 minutes, depending upon the thickness, and cooling rapidly in air or quenching heavy sections in water. For alloy C, the temperature is a little higher—2200 to 2225° F.—for 2 to 3 hours according to the section, and rapid air cooling is used. Such a treatment is similar to the softening of austenitic steels—namely, holding at heat and then cooling rapidly.

The stabilizing anneal is frequently used before welding A, B, or C sheet to prevent deterioration adjacent to welds, when heat-treatment after welding is not practical. It is also used after welding to reduce the loss of corrosion resistance and toughness that may result from exposure of a part of the welded structure to temperatures between 1200 to 1900° F. This treatment is most effective when preceded by the full anneal. For alloys A and B, it consists of holding for 2 to 4 hours at a temperature between 1925 and 1950° F. and air cooling. Alloy C should be held for the same time at the higher temperature of 2050 to 2075° F. and also cooled in air.

In conclusion, any competent welding operator can become proficient in welding these alloys, and by taking advantage of the experience already gained in the work described, he can turn out a job that will measure up to the most exacting standards.

X-Ray Diffraction

ARTICLE 1
Basic Principles and Theory

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THE extent to which the human eye can resolve structures is fixed by the wave length of light and the resolution of the optical system used. The maximum resolution obtained so far, using ultraviolet light and special optics, is in the region of 1000 Å. (10^{-5} cm.)

This resolution however, while adequate for most purposes can be used only for the study of agglomerates or gross structures. Similarly the more recently developed electron microscope is capable of magnifications up to 250,000 diameters or more with a maximum resolution of about 50 Å or so.

Studies made by these very valuable instruments are limited, however, and even though the resolution be increased greatly, their function still will be limited to agglomerate study. X-rays on the other hand have a wave length of the same order of magnitude as the basic repeating structures of matter, and consequently can be used to analyze these atomic structures.

Since the physical properties of matter, such as molecular weight, physical appearance, thermal expansion, conductivity both thermal and electrical, chemical activity and most other physical properties of matter in gaseous, liquid, or solid states, are entirely dependent on the atomic arrangement, it must necessarily follow that studies of the ultimate form of matter are very important in any work where physical or chemical properties of materials have significance.

Theory of Diffraction of X-rays

Regularities in the ultimate structure of matter are found when the electrical forces which act between atoms or groups of atoms are in equilibrium: This regular array of atoms can be represented by a 3-dimentional set of points through which can be passed an infinite number of sets of parallel planes. Von Laue first suggested that such a regular structure can act as a diffraction grating for x-rays.

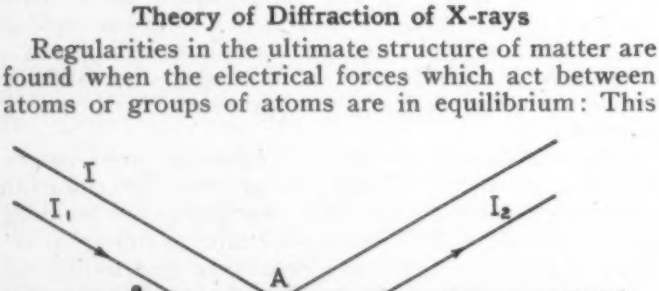

FIGURE 1

Since most matter is made up of atoms arranged in some sort of regular fashion it follows that if monochromatic radiation of known wave length is used, and the scattering material under observation is considered to act as a diffraction grating, the resultant diffracted beams will appear at different angles depending on the geometry of the grating. However, since the grating is not a simple linear affair as is used in light spectroscopy but rather is periodic in three dimensions, it follows that the ordinary laws of diffraction of light by an optical grating need not necessarily be applicable.

It is interesting to note that Von Laue gave the first mathematical treatment of x-ray scattering by a three dimensional periodic array of atoms, i.e. by a crystal. He considered each atom as being bathed in the x-ray beam and acting as an x-ray scattering center. In most directions the scattering by the individual atoms had such phasal relationships that destructive interference occurred and no strong beam of radiation could be observed. However, he showed that it was possible to find certain special directions in which the geometric relationships were such that the scattered waves from the atoms constituting the crystal were in phase. These special conditions are known as the "Laue" conditions and the strong x-ray beams which could be observed in those directions are known in terms of Bragg's treatment as reflected beams.

Laue's treatment, while fundamental and exact, is quite complex mathematically, and its forbidding character actually inhibited the use of x-ray for structural investigations. However, shortly afterwards, the Braggs showed that Laue's treatment was actually equivalent to considering the x-rays as being reflected by sets of parallel planes (Bragg planes). These Bragg planes are simply related to the crystallographic planes so well known to the classical crystallographer for decades.

Figure 1 shows the conditions necessary for effective diffraction to occur. On the drawing, d is the spacing of similar parallel planes, Θ is the angle of reflection, and I_1 is the direction of the incident radiation. The incident beam ($I\ I_1$) is reflected at A and C. AB and AD is perpendicular to I_1, C and CI_2 respectively. The path difference between ray I_1 and I is given by $BC + CD$ where $BC = d \sin \Theta$.

For I_1 to have constructive interference with I, $BC + CD$ must equal an integral number of wave lengths λ or

$$n\lambda = 2d \sin \Theta$$

n = an integer (or whole number)
λ = wave length of characteristic radiation in Angstroms (10^{-8} cm.)
d = interplanar spacing
Θ = Bragg angle

This is the fundamental equation which forms the

THIS is the first of three articles in which applications of the X-ray to the petroleum laboratory will be considered. In this first discussion the basic principles of the X-ray have been set forth.

These rays have a wave length "of the same order as the basic repeating structures of matter." Matter is a condition of atomic arrangement. Consequently the X-ray has its place as a tool for examination.

In the succeeding articles the author will consider the constitution of matter and then discuss applications of X-ray diffraction to petroleum and related products.

basis of x-ray diffraction studies of crystalline materials.

The x-rays commonly used in diffraction work are produced when an electron is ejected from the "K" shell of an atom and subsequently the K shell is filled up again by an electron falling into the vacant spot from an outer shell. In order that this can occur it is necessary that an electron stream of sufficient velocity to ionize the K shells strike the atoms of the target. In practice this is achieved by using a hot filament as the electron source and a selected metallic surface as the target, all enclosed in a sealed off vacuum tube. A high voltage source is then used to accelerate the electrons, thus giving them sufficient energy to excite the K shell. This H.T. source is connected between the filament and target, and x-rays are eventually generated as a result of the impact of the electron stream on the target surface.

If a high voltage equal to, or greater than, a certain minimum (excitation potential) voltage is applied, so-called characteristic radiation is emitted, which has a spectral distribution of intensity that is characteristic of the target material. Such a distribution for a copper target is shown in Figure 2.

By far the largest part of the energy of the electron stream is transformed into heat at the target surface, and for that reason it is somewhat impractical in sealed-off tubes to use low-melting-point metals for the target materials. The target materials found most useful in general practice are Mo, Cu, Co, Fe and Cr. In order to dissipate the heat, these targets in modern x-ray tubes are water cooled, since the continuous energy dissipation sometimes exceeds 1500 watts.

The useful characteristic radiation consists of three predominant intensity maxima of different intensities, the $K_{\alpha 1}$ $K_{\alpha 2}$ and $K\beta$ radiation having a rough relationship of intensity of 1:0.5:0.15 respectively. The $K\alpha_1$ $K\alpha_2$ are together known as the $K\alpha$ doublet since they are relatively close in wave length and a weighted value of λ is used for computation in average work. However, when high precision measurements are required, the resolution of the doublet is obtained, and the wave lengths of the individual members of the doublet are used.

The presence of the K_β is in many cases a disadvantage, especially in the examination of powder samples, since it introduces an extra line, which can be

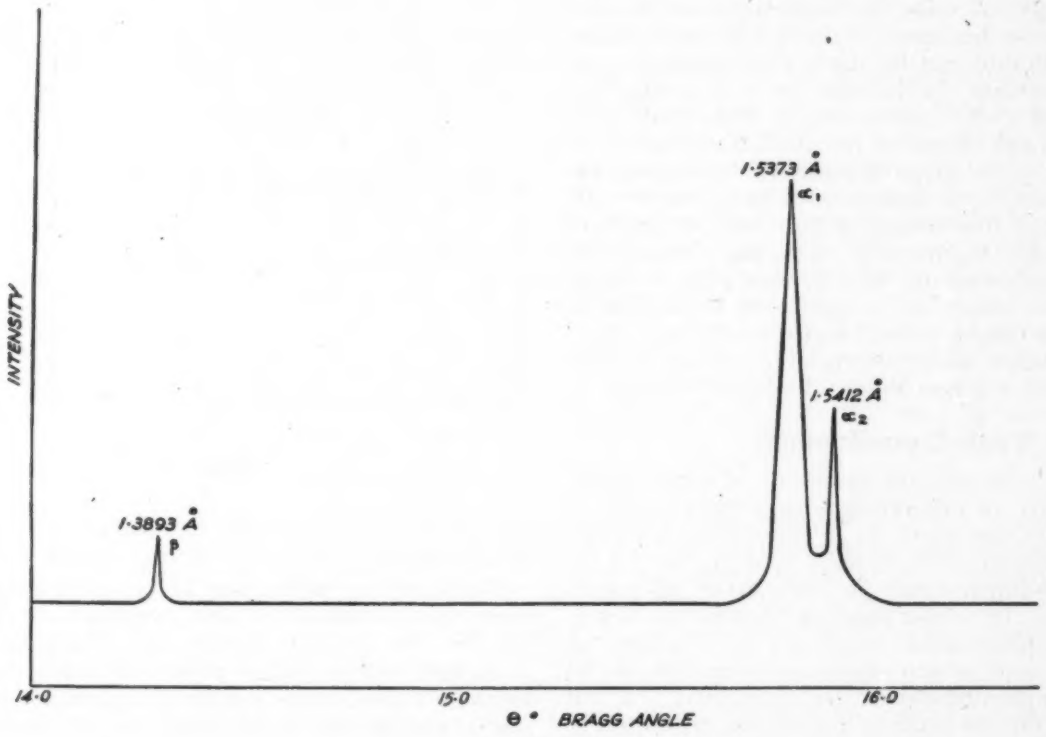

FIGURE 2

confusing into the pattern. The β radiation can be lowered in intensity by use of either a crystal monochromator or selective filter of suitable thickness as indicated in Figure 3. This filter thickness is designed to lower the intensity of the K_β to 1 percent of the $K\alpha_1$.

X-rays, upon passage through matter, lose energy both by scattering and transformation into the energy of moving electrons. The degree of absorption of the radiation in a material is dependent on both the nature of the material and the wave length of the radiation. With monochromatic radiation, such

TARGET	Excitation Potential KV Min.	Characteristic λ in. A°		Rel. Intensity		Filter for Kβ	Filter Thickness Inches x 1/1000
		Kα1	Kα2	Kα2 / Kα1	Kβ / Kα1		
Mo	20.0	0.7078	0.7128	0.506	0.233	Zr	7.0
Cu	9.0	1.5373	1.5412	0.460	0.158	Ni	0.75
Co	7.7	1.7852	1.7891	0.532	0.160	Fe	0.70
Fe	7.1	1.9321	1.936	0.491	0.182	Mn	0.65
Cr	6.0	2.2850	2.2889	0.506	0.210	Va	0.75

FIGURE 3

as the K∝ characteristic band, the absorption can be expressed by the exponential law

$$I = I_o e^{-\mu l t}$$

where I = incident intensity
I_o = transmitted intensity
μl = linear coefficient of absorption ($\mu_m \rho$)
(obtained from published data)
t = thickness of sample in centimeters

It is possible, from this information, to compute the optimum specimen thickness to obtain the maximum intensity in a diffraction pattern. This optimum value for the usual powder method is $2/\mu l$ cm.

A certain phenomena known as K absorption, with the formation of K absorption edges, is caused by the fact that as soon as a quantum of radiation has sufficient energy to excite the K shell it does so, and so the absorption becomes peaked. For this reason Cu radiation should not be used with samples containing iron because the K edge for iron is slightly longer than the CuK∝ wave length. This leads to a high degree of excitation of the FeK lines, which is demonstrated by the large amount of fluorescent radiation observed. Such fluorescence in a sample will cause fogging of the recording film and obliteration of the line detail. Figure 4 gives K edge absorption values for some elements. As a general rule, if the K edge absorption value for a specimen is within 20 percent on the longer wave length side of the characteristic radiation used, appreciable excitation will occur and another target material should be used.

X-ray Crystallography

One of the most valuable functions of x-ray analysis is the ability to differentiate between crystalline and amorphous materials. In a crystalline material, the atomic arrangement is such that it can be referred to a 3-dimensional periodic array of points (lattice points). In non-crystalline (amorphous) materials such 3-dimensional regularity is not observed.

The lattice array which represents a crystal can be described by a parallelopiped (the unit cell). The unit cells, piled up on one another like bricks, reproduce at their corners the points of the lattice. To completely describe a crystal structure one needs first to describe the size and shape of the unit cell and then describe the disposition of the contents of the unit cell, i.e. the arrangement of the repeating group of atoms which constitutes the cell contents. Different kinds of crystals have different types of space lattices.

Since the differences between one space lattice and another are determined by the differences in the axial lengths and the inter-planar angles, it follows that the dimensions of these axial lengths and angles are required to define the cell. A simple form of a space lattice is shown diagrammatically in Figure 5.

ELEMENT	K Absorption Edge Å
Mg	9.4962
Al	7.936
Cr	2.0659
Mn	1.8916
Fe	1.7394
Co	1.6040
Ni	1.4839
Cu	1.3774
Zr	0.6874
Mo	0.6184
Ag	0.4845
Ba	0.3308
W	0.1782
Pt	0.1577
Au	0.1534
Pb	0.1405

FIGURE 4

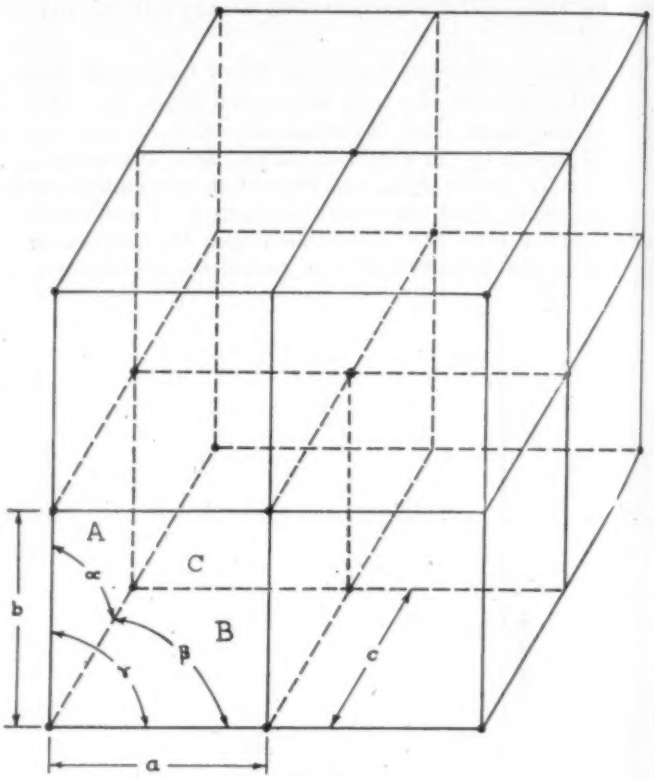

FIGURE 5

The unit cell shown thus has axes a, b, c and interfacial angles of ∝, β and γ at the origin O.

There are actually only 14 types of space lattices even though there are many thousands of crystals known. The shape is always that of a parallelopiped. If in addition to lattice points at the corners, there are also points at the center of a face, i.e. in the center of the A face it is called an "A" face centered lattice. When all faces are centered, it is called a face centered or "F" centered lattice. If a point is at the center of the body diagonals it is called an "I" centered lattice. An hexagonal lattice is designated by "H" lattice. (Here a = b, γ = 120°, and c is perpendicular to "a" and "b.")

A rhombohedral lattice, R, is so defined that a = b = c, ∝ = β = γ ≠ 90°. A cell with only lattice points at the corners is called a primitive cell (symbol P). Centered cells are obviously not primitive. Each lattice point can represent an atom or group of atoms, identically placed and oriented in space. The space lattices are tabulated in Figure 6.

Crystal planes are designated by three indices hkl, the Miller indices. These indices are fixed for a given

SYSTEM	Axes	Angles	Types of Cell
1. Triclinic.....	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90°$ all unequal	1 kind (primitive) P.
2. Monoclinic.....	$a \neq b \neq c$	$\beta \neq 90° = \alpha = \gamma$	2 kinds P., C. (A.)
3. Orthorhombic...	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90°$	4 kinds P. B. F. I. A. C.
4. Tetragonal.....	$a = b \neq c$	$\alpha = \beta = \gamma = 90°$	2 kinds P. I.
5. Cubic.....	$a = b = c$	$\alpha = \beta = \gamma = 90°$	3 kinds P. F. I.
6. Hexagonal.....	$a = b \neq c$	$\alpha = \beta = 90°$. $\gamma = 120°$	1 kind
7. Rhombohedral..	$a = b = c$	Can be referred to hexagonal axes $\alpha = \beta = \gamma \neq 90°$	1 kind
			14= Total

FIGURE 6

set of crystal planes when the unit cell is chosen. The (hkl) set of planes divides the "a" axes in "h" parts, the "b" axis in "k" parts, the "c" axis in "l" parts. It is obvious from the definition that h,k,l are always integers.

If the intercepts are negative then the indices are negative with the minus sign being written over the integer. If atomic planes intercept each other in parallel edges, they are said to be in the same zone. The straight line lying parallel to these edges is called the zonal axis. The most striking property of perfect crystals is their symmetry. Each type of crystal is described by a group of symmetry elements that will give rise to only one form of crystal and no other.

It is possible to have 32 different point groups of symmetry elements and they can be used to describe any crystal form in a unique fashion. A group of symmetry elements is termed a point group which is independent of the crystal form. An operation on a crystal whereby it is brought into self-coincidence is called a symmetry element. The possible symmetry elements are:

(1) Rotation axis (can be 2, 3, 4 and 6 fold)
(2) Reflection plane of symmetry
(3) Center of symmetry

In each crystal system the class of crystals having the highest symmetry is called holohedral, those with half the maximum possible symmetry, hemihedral, etc. Space lattices have the highest possible symmetry of the systems to which they belong. However, it is possible for the patterns grouped around each lattice point to confer on the structure a lower symmetry than that of the lattice itself. These variations in symmetry are due to the different arrangement of the atoms in the unit cell. Such variations in symmetry are termed space groups. The total number of possible space groups is 230.

The inter-planar spacing "d" of a set of planes of index hkl is usually written d_{hkl}. The term d_{hkl} can be expressed as a function of the unit cell dimensions (a, b, c), and ($\alpha\beta\gamma$) and the indices of the reflecting plane. These relationships are simple for cubic, tetragonal and orthorhombic systems, but are very complex for other types of crystal structure. Here are a few examples:

For a *cubic* cell:

$$d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

Tetragonal cell:

$$d_{hkl} = \frac{1}{\sqrt{\frac{h^2}{a^2} + \frac{k^2}{a^2} + \frac{l^2}{c^2}}}$$

Orthorhombic:

$$d_{hkl} = \frac{1}{\sqrt{\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}}}$$

d	2.23	1.921	1.358	d in A .708	$\frac{I}{I_1}$
$\frac{I}{I_1}$	1.00	0.66	0.27	2.23	1.00
				1.921	0.66
				1.358	0.27
I	30	20	8	1.159	0.27
				1.110	0.03
Mn_4N Manganese Nitride					

FIGURE 7

Technique of Powder Identification

Since the greater bulk of material available for study is in the form of small crystals or agglomerates, and rarely as perfect single crystals, a simple method has been developed for identification of such materials. This technique is known as the powder method, and is adaptable whenever a sample is obtainable in even as small a quantity as 1 milligram.

Bragg's law, as derived previously, was given as $n\lambda = 2d \sin \Theta$. n = the order of reflection, in this case can be regarded as unity by including it in the d_{hkl}. Rearrangement of the terms gives: $d_{hkl} = \frac{\lambda}{2 \sin \theta}$ Thus if λ is known, and the Bragg angle Θ determined, it will be obvious that a value for "d" or the interplanar spacing can be computed.

By measuring all the angles of reflection $\Theta_1, \Theta_2, \Theta_3$ etc., a corresponding set of values for "d" can be obtained d_1, d_2, d_3, etc. These so-called sets of "d" values are unique for any one substance. If any other substances are present in the sample, they will give reflections separately as if they alone were present.

The intensity of the separate diffracted beams are not necessarily alike, but for any one substance the intensities of the beams at spacing values d_1, d_2, d_3 and so on will always have a definite relationship to each other. Thus we can establish a list of "d" values and their corresponding intensities for any one crystalline substance, that will be unique. This provides a method of identification of unknown samples, providing a standard set of "d" values and their relative intensities have been prepared, for chemically and crystallographically similar substances of known composition.

A card-index system has been published giving "d" values and their relative intensities for some 1500 chemical identities. The system is in terms of "d" values, the order of listing being in order of spacing. A separate card is provided for each of the 3 stronger lines of each substance. A sample card from this index is given in Figure 7. The three strongest lines it will be noticed are listed under "d." Their intensities relative to each other are listed under $\frac{I}{I_1}$. The third index I lists the strength of the line in relationship to that obtained from a standard substance, so that quantitative determination of two or more unknowns can be computed. The other lines on the card that are listed are the total number of line "d" values and their relative intensities that might be expected for the particular substance.

Thus we have a system of quantitative and quali-

tative identification of a large number of substances that will be gradually added to as time goes by. Modern practice, and design of equipment used for x-ray diffraction has simplified the practical aspects of investigations, so that now, comparatively unskilled operators can obtain results in a short time, and of an accuracy that was considered impossible not so long ago for other than advanced qualified investigators. This means that plant laboratories can successfully obtain and interpret results by diffraction methods in a unique fashion without augmenting their staff with highly paid experts.

X-ray Equipment

A modern diffraction apparatus is shown in Figure 8. The high voltage is obtained from a high capacity (50 milliamperes and 60 kilovolts) water-cooled transformer with full wave rectification. Control of voltage and milliamperage is stepless and with good regulation. The total high voltage supply unit with controls, safety devices, water-supply regulators and meters is enclosed in a steel cabinet surrounded by an adequate instrument table of cast metal which

FIGURE 8

also supports the pillar type shockproof and rayproof x-ray tube.

The tube housing is made of a massive bronze casting and is water-cooled, the cooling water also being used for cooling the target of the x-ray insert tube. The housing has four faces machined normal to the direction of the x-ray beam. These faces each carry a filter selector disc, with built-in filters, so that if the x-ray tube is changed, the appropriate β radiation filter can immediately be turned into place.

The x-ray tube insert is a four-window, high-power, water-cooled type, that can be interchanged for another in about four minutes. This changing of the tube does not alter the position of the emergent beam, which means that cameras and other equipment do not have to be realigned every time the tube is changed. The cameras are supported by adjustable brackets provided with precision tracks, so that the cameras can be replaced after removal for loading, with great accuracy.

Special types of cameras, such as the Weissenberg goniometer for single crystal studies, can be accommodated by placing them on the machined table surface and moving up to the x-ray portal. Because of the four-window tube, as many as four cameras (or less) can be in position at one time, which means a saving in total operating time per exposure. For the powder-identification work previously described a powder camera of the Debye-Scherrer type is desirable and is in general use. Such a camera of modern design is shown in Figure 9.

The x-rays are brought down to a fine pencil of radiation by a collimator, 0.5 mm. or 1.0 mm. in diameter. The specimen is reduced to about 200 mesh agglomerate size and can be introduced into a thin-walled capillary tube about 0.3 mm. in diameter. It can also be prepared by smoothly coating the outside of a thin glass fiber with a paste of the powder specimen and some adhesive such as collodion, until a diameter of about 0.3 mm. is obtained.

The specimen mount can be seen at the center of the camera and is rotatable by means of a geared motor mounted on the bracket. The specimen can be accurately centered in the x-ray beam by an external adjusting screw and can be viewed through a lens system that fits on the beam tube, diametrically opposite the collimator tube. The beam tube's function is to prevent the air scattering (from the primary beam) from hitting the film and thus producing fogging.

The film, 35 mm. wide, fits around the inside diameter of the camera and is held tightly against the metal, by a screw tensioning device shown on top of the camera body. The collimator and beam tube pass through holes punched in the film. When the exposure is made, and the film developed, and laid out, it will be seen that the complete diffraction pattern will be recorded. With this type of film mounting it is possible to compensate for a number of instrumental errors that can creep in with ordinary cameras. This is called the Straumanis technique and makes the film self-calibrating for precision measurements. Such deviations as variation of camera diameter and film shrinkage are compensated for. Such a film is shown in Figure 10.

The camera diameter in general use is 115.1 mm. so that after average film shrinkage, each 2 mm. measured on the film from the central beam position to a diffracted line, represent 1° Bragg angle or θ. Thus after application of any corrections required to compensate for film shrinkage and camera diameter, and substituting in the Bragg's law formula, one can evaluate "d" values for all the lines. The relative intensities of the lines can be determined either by a densitometer or by matching against a standard calibrated photographic step wedge.

X-ray Diffraction Spectrometer

Very recently, a new instrument—the result of many years of development work—is available. It is known as the x-ray diffraction spectrometer and eliminates the use of film with the attendant darkroom. The unit consists of a highly stabilized x-ray source and an analyzing goniometer, with a sensitive, quantitative, radiation measuring device, and associated circuits.

Instead of the customary geometry of the powder camera, a focussing system for the x-rays is used so that intensities of the diffracted radiation are about 20 times that obtained with the usual powder camera. The coherent radiation from the specimen is picked up by a Geiger-Muller tube and its intensity

FIGURE 9

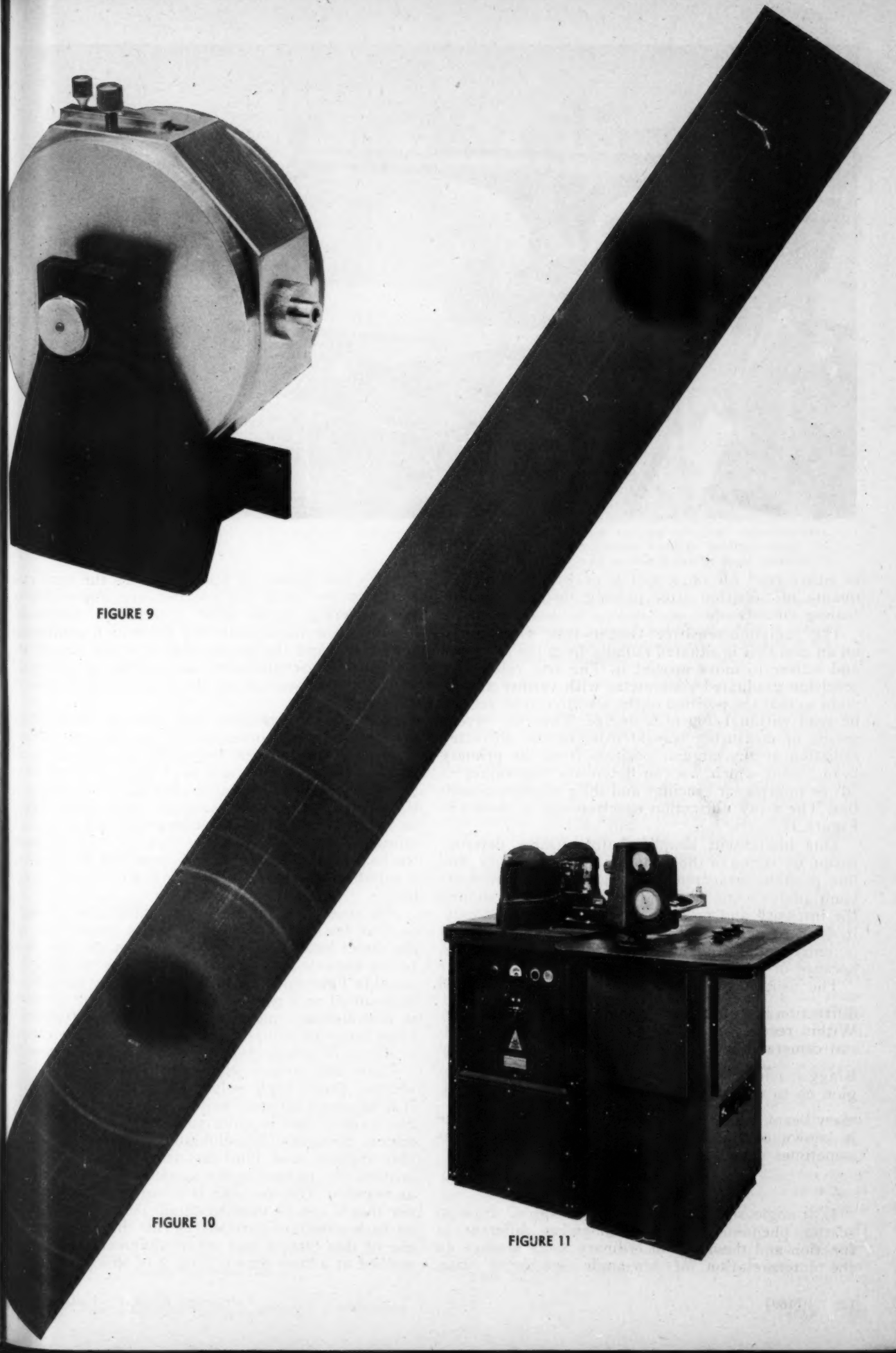

FIGURE 10

FIGURE 11

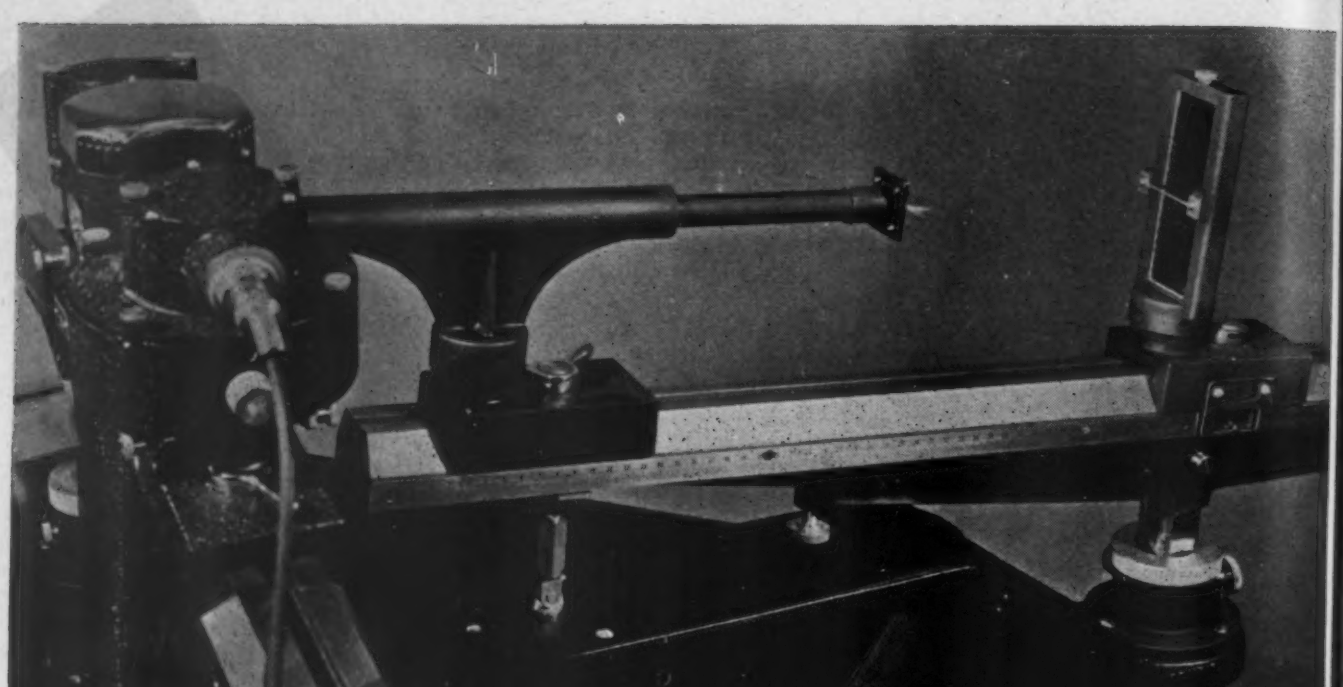

FIGURE 12

is either read off on a meter, or by counting the quanta of radiation after passing through suitable scaling circuits.

The radiation-sensitive Geiger tube is mounted on an arm that is situated radially from the specimen and is free to move around it. The arm rides on a precision graduated goniometer with vernier attachment so that the position of the sensitive analyzer can be read within 1/100 of a degree. Thus we have a means of measuring the intensity of the diffracted radiation at any angular position from the primary beam, from which we can determine the values of "d" or interplanar spacings and their relative intensities. The x-ray diffraction spectrometer is shown in Figure 11.

This instrument simplifies quantitative determination by virtue of the accuracy of the intensity, and line position measurements. Since a complete spectrum analysis can be made in 25 minutes or so, and the intensity and position of one or two lines only, in 5 or 10 minutes, this machine becomes of great potential value in plant control and routine analysis, because of its speed and simplicity.

The usual type of diffraction camera can record diffraction lines between 0.5 and 20 Å approximately. Within recent years investigators by means of special cameras have worked in the region in terms of Bragg spacings between 20 and 1000 Å. This is the region up to within 5 minutes of arc or so, of the primary beam. This region above 20 Å in spacing value is known as the low-angle scattering region or is sometimes called small-angle scattering.

Low-Angle Scattering

Low-angle scattering is a rather special type of scatter phenomena and is somewhat different in function and theory from ordinary x-ray studies. In the interpretation of low-angle scattering data, Bragg's law cannot be applied unless the rare case occurs where clear cut maxima are observable in the scattering region under observation. Generally, however, low-angle scattering presents a continuous appearance and the determination of the size of the geometrical discontinuities responsible for it is based on an intensity analysis of the angular distribution of scatter radiation.

So far, its greatest use has been in cases where the material under investigation contains no obvious discrete discontinuities, but rather consists of small agglomerates. Particle size is often of importance in the correlation of physical or chemical behaviorism of the material studied. Because the x-ray beam has to be kept small in order to observe scattering up to 5 minutes of arc, it is obvious that the collimation of the beam must be good. This is provided for by using a suitably designed collimation system over 35 cm. long.

The specimen, usually 0.3 mm. thick, is arranged so that the collimated beam passes through it and the direct beam is received by a beam stop bar fixed to the camera. Behind the beam bar is the film in a suitable light-tight cassette. The whole assemblage is mounted on a precision track so that the specimen to film distance can be accurately adjusted within a large range of values. The low-angle scatter camera is shown in position on the x-ray unit in Figure 12.

There are certain studies such as orientation in metals, fibers, high polymers and other materials that require a different type of camera. This is a flat film camera and is quite simple in construction. It merely consists of a collimator, supported in a suitable manner and film cassette with support that enables one to change the specimen to film distance as required. The specimen is mounted in such a manner that it can be used to obtain either transmission or back-reflection patterns as can the cassette. The use of this camera and other equipment will be described at a later date in Part 3 of this series.

A STUDY OF THE Composition of Petroleum Waxes FROM WESTERN CRUDES

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THE chemical composition of paraffin wax long has been a controversial subject, and the meager data which has been collected over a period of years is difficult of correlation. The problem is further complicated by the great diversity of raw materials. The waxes removed from different crude oils present strikingly different characteristics, and the results of one worker studying the wax from a particular crude cannot justifiably be applied to the wax from another crude. Methods of refining also produce different results.

The aim of the present work has been to lay the groundwork for complete investigation of one particular wax. The material selected is relatively new, and as far as known there has been no data published relative to it in the past.

DATA relative to the constitution of paraffin wax is very incomplete, and the literature presents no data on the composition of the wax removed from Western crude oil by the solvent dewaxing process. The object of this work is to lay the foundation for a complete investigation of this type of material.

A sample of paraffin wax from a California crude oil supplied by Union Oil Company of California, was subjected to a careful vacuum distillation, yielding 48 final fractions of widely varying physical characteristics. Melting points, molecular weights, cooling curves, refractive indices, and specific gravities were determined on all samples.

A detailed discussion of the data is presented, and it is compared with the best accepted values for the physical constants of synthetic hydrocarbons. The lower-melting fractions probably consist principally of normal paraffins; naphthenic compounds may be present in the higher-melting fractions.

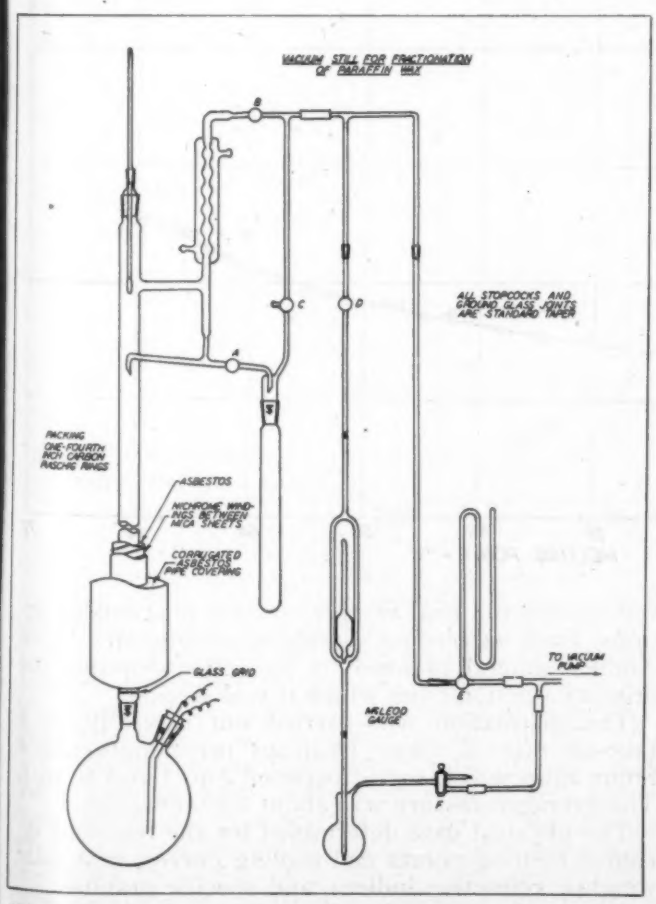
VACUUM STILL FOR FRACTIONATION OF PARAFFIN WAX
ALL STOPCOCKS AND GROUND GLASS JOINTS ARE STANDARD TAPER
PACKING ONE-FOURTH INCH CARBON RASCHIG RINGS
ASBESTOS
NICHROME WINDINGS BETWEEN MICA SHEETS
CORRUGATED ASBESTOS PIPE COVERING
GLASS GRID
TO VACUUM PUMP
McLEOD GAUGE

FIGURE 1 Vacuum distillation column

The results of recent researches in this field, most of which were conducted on waxes from Mid-Western oils,[1,2,6,7,10,13] all point to the fact that these waxes are composed chiefly of normal paraffin compounds. Smaller quantities of other compounds, the nature of which is in doubt, are reported to be responsible for the varied nature of the waxes.

The material used in this investigation, "Aristo-wax 145-50," is recovered from waxy distillate from asphaltic crude oils by Union Oil Company of California. The oil comes principally from Santa Fe Springs, with a smaller amount from Kettleman Hills. Still smaller amounts are obtained from other California fields. The wax is removed by solvent refining, and is hard, pure white, slightly more opaque than paraffin wax from Mid-Western or Eastern crudes. Its A.M.P. melting point, as indicated by the name, is between 145° F. and 150° F. A companion product, "Aristo-wax 160-65," which was not investigated in this work, is recovered from stock of higher viscosity, and appears similar except in melting point.

Experimental Procedure

Separation of paraffin wax into its component parts can be accomplished readily by fractional distillation under vacuum. Previous workers have used various arrangements for carrying out this work[2,6,7,13] but the use of an efficient fractionating column is indicated in order to accomplish the high degree of separation necessary. The apparatus used in this work provides for reflux control and for more or less

continuous operation, and is shown schematically in Figure 1. the packed section of the column is 36 inches long and is packed with quarter-inch Raschig rings.

Francis, Watkins, and Wallington[8] observed that little fractionation took place after about 15 simple distillations of a Scotch shale wax. The column used in this work is equivalent to a plate column of 7 to 8 theoretical plates,[14] hence at high reflux ratio, two distillations might nearly be equivalent to the maximum separation possible. With this thought in mind, the decision of the author was to fractionate twice.

The maximum amount of material that could conveniently be handled at one time in the pot was about one liter. Since this was not a sufficient quantity to furnish samples of a large enough size for testing, four similar primary distillations were carried out, and the corresponding fractions combined for final distillation. Each succeeding fraction from each distillation was denoted by a letter, hence, the first fraction from each primary distillation was labelled "A," the second "B," etc.

For the final distillations, the corresponding fractions from the primary fractionations were combined. Distillation of these samples was continued until the the next higher-boiling set of fractions was added and the process continued. In this way, all of the residue in the pot reached a low level, at which time wax except the final residue was cut into small fractions. Each succeeding sample was designated by an Arabic numeral prefixed by the letter denoting the primary fraction from which it was distilled.

The distillation was carried out carefully, at a take-off rate of about 12 drops per minute and a reflux ratio which varied between 5 to 1 and 10 to 1. The average pressure was about 0.20 mm. Hg.

The physical data determined for the fractions included melting points and cooling curves, molecular weights, refractive indices, and specific gravities.

The method used for determining melting points

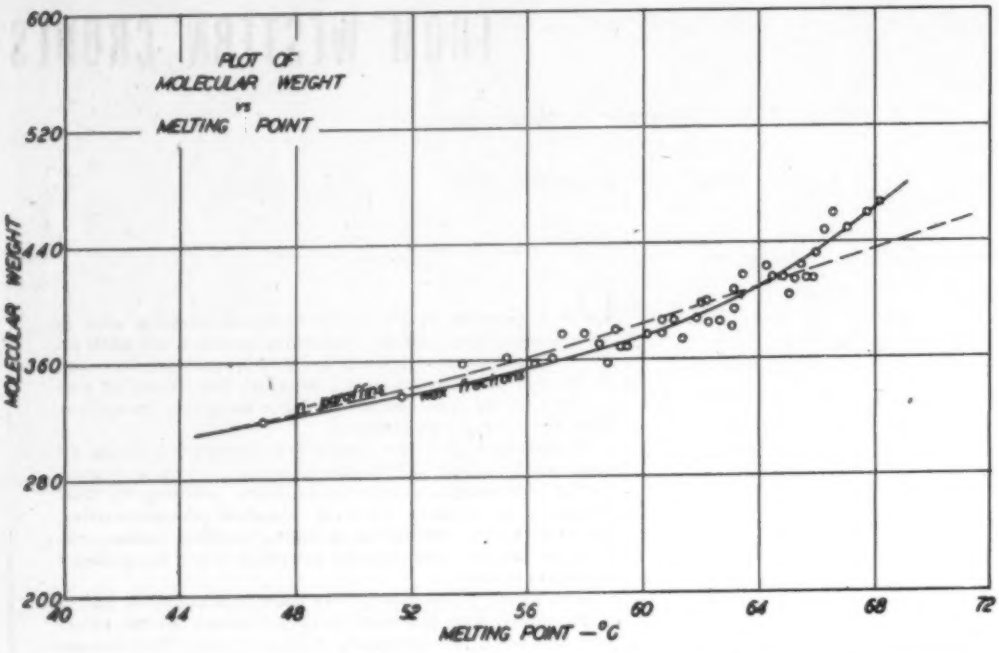

FIGURE 2—Molecular weight as a function of melting point

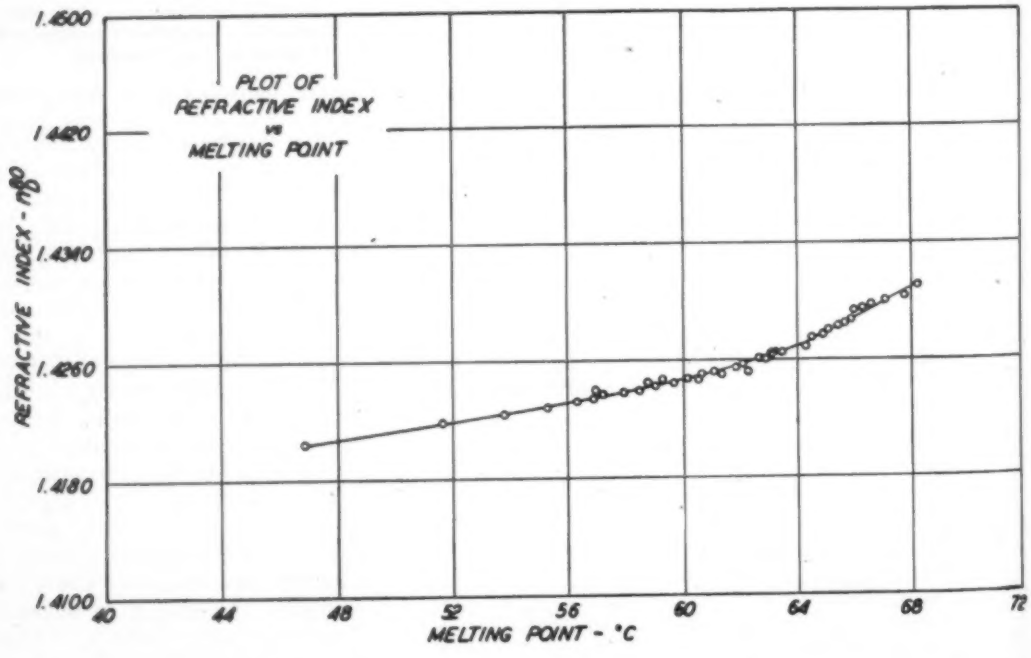

FIGURE 3 — Refractive Index as a function of melting point

was the ASTM standard method No. D-87-37. The cooling was continued after the melting point was reached, and the curve thus obtained was used as the cooling curve for the particular wax under investigation. These curves cannot be used directly in comparison with cooling curves reported in the literature which were determined under different conditions. They do, however, provide a very useful comparison between the cooling characteristics of the several waxes reported in this paper.

Molecular weights were determined by the ebullioscopic method of Menzies and Wright.[10,11] The solvent used as benzene, and synthetic normal-tetracosane was used as a standard solute.

Refractive indices were obtained by the use of an Abbe Refractometer. They were read at a temperature of 73° and were extrapolated to 80° by the use of an experimentally determined value of dn/dt.

Specific gravity was measured with an API hydrometer. Through the use of tables published by the United States Bureau of Standards[4] these were converted to densities at 80° referred to water at 4°.

The results of all tests are presented in tabular form in Table 1. The melting points are probably the most reliable values obtained; therefore they have been used to correlate the data. A plot of molecular weight versus melting point is shown in Figure 2. Included in this plot is the line for the accepted values of the normal paraffins as reported by Egloff.[5] The values of refractive index and density are shown plotted against melting point in Figures 3 and 4.

An important method of correlating density and refractive index is afforded by the quantity known as "molecular refraction." This value is plotted against molecular weight in Figure 5. The calculated values of molecular refraction obtained as described by Getman and Daniels[9] are included for the paraffins, olefins (which coincidentally fall on the same line), naphthenes, and straight-chain aliphatic esters.

The cooling curves shown in Figure 6 indicate that

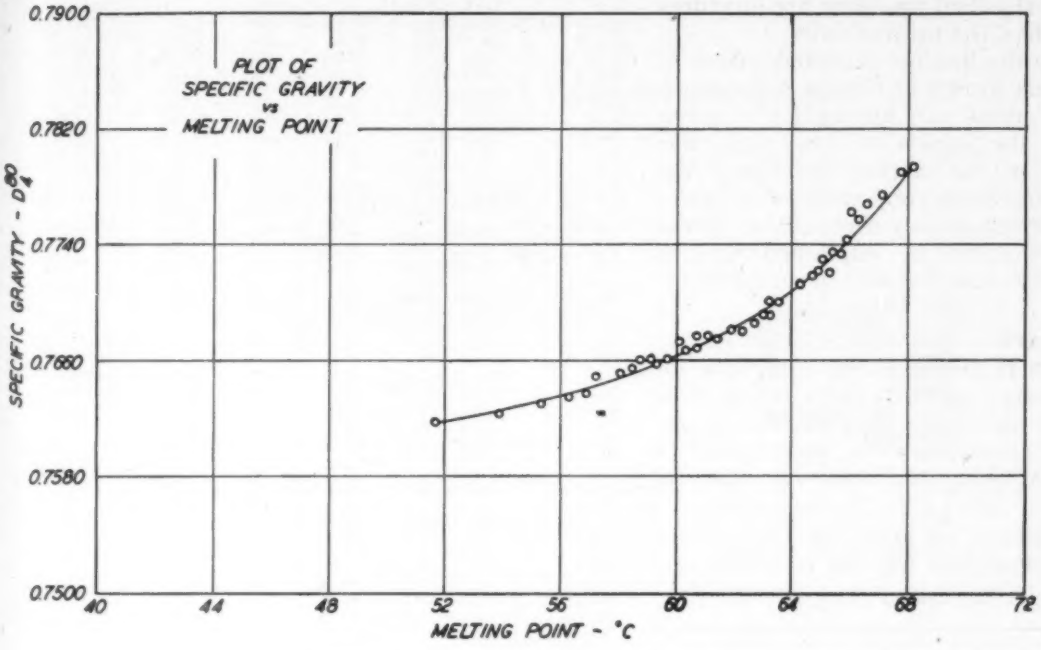

FIGURE 4 — Specific gravity as a function of melting point

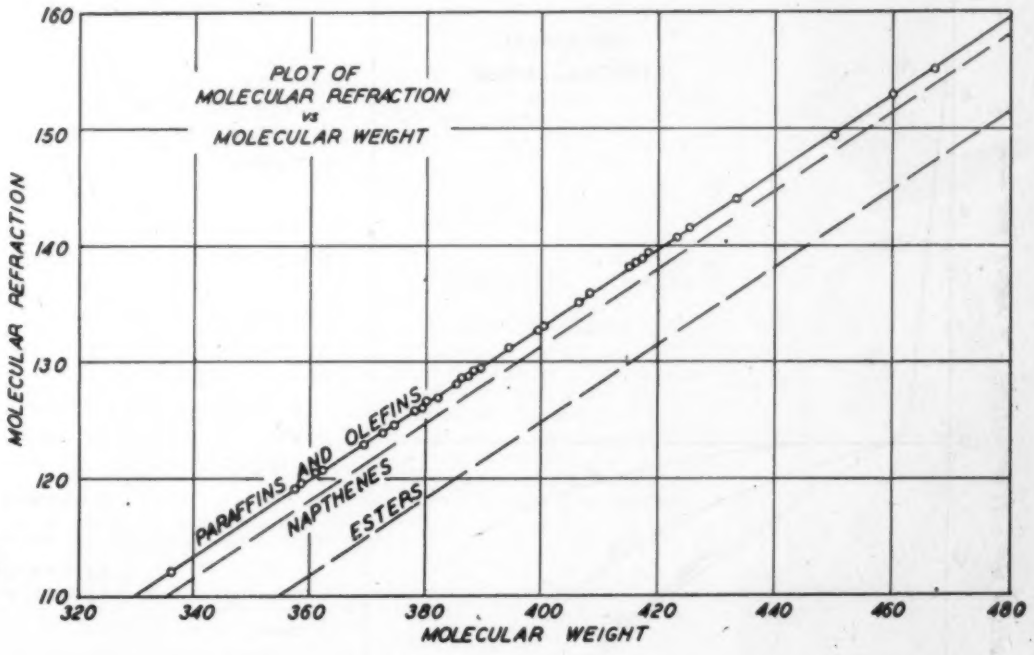

FIGURE 5—Molecular refraction as a function of molecular weight

good separation was obtained. Cooling curves were run on all samples, but only three representative curves are shown to avoid the confusion that results from attempting to plot all of the curves on one graph. On this plot, three curves have been superimposed as if the melting points were the same. The curve from sample III-A, from a primary distillation is much flatter than that of the original wax. Likewise, the curve for the final fraction, A-5, is still flatter, indicating that the final fractions are mixtures of fewer compounds than the original wax.

As can be seen from the line for accepted values of n-paraffin hydrocarbons shown in Figure 2, the melting points of the fractions are higher for a given molecular weight in the region of low molecular weights. However, for the higher fractions, the melting points of the fractions are considerably lower than those of the corresponding n-paraffins. These lower melting points could be explained by the presence of either branched-chain or naphthenic compounds.

In general, the refractive indices and densities are lower than the values reported in the literature for true n-paraffins. However, in most cases where such compounds have been reportedly isolated from petroleum, these physical constants have been found to have lower values than when the material was produced synthetically.

All experimental values for molecular refractions fall directly on the theoretical line for paraffins and olefins. The difference between the theoretical values for these compounds and the naphthenes is, perhaps, too small to allow any positive conclusions to be drawn regarding the presence or absence of such compounds.

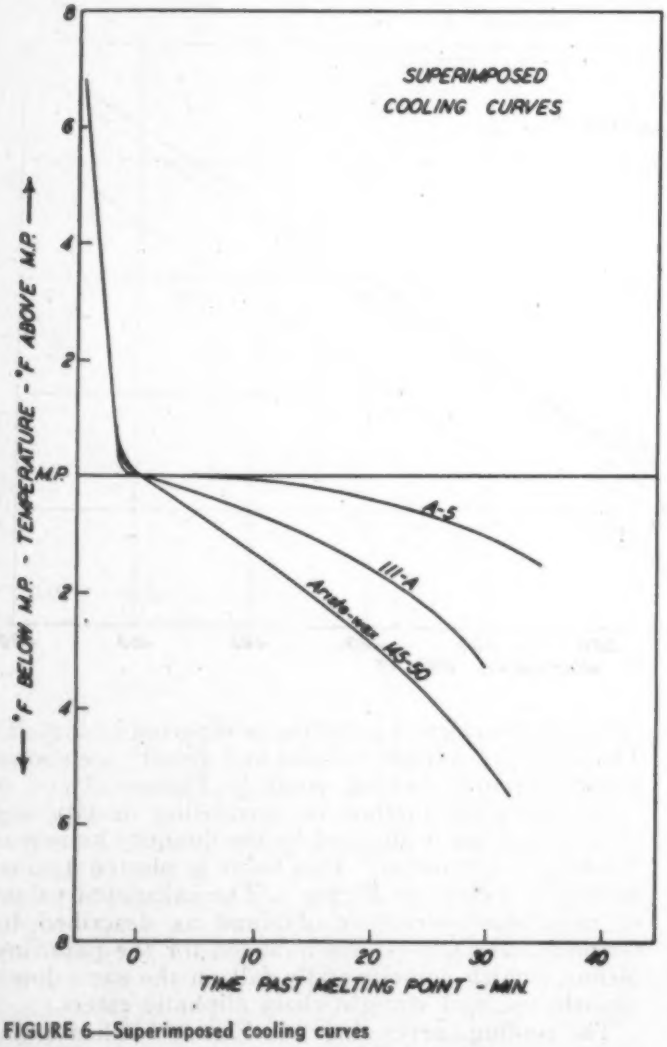

FIGURE 6—Superimposed cooling curves

TABLE 1

Physical Constants of Final Fractions

Sample No.	Boiling Range °C. at 0.2 mm	Melting Point °C.	Mol. Weight	Sp. Gr. 80 D_4	Ref. in 80 n_D	Mol. Ref. Mr
A-1	107.5—152.0	.....	...	.....	1.4207	112.0
A-2	152.5—166.0	46.95	319	.....	1.4203	.....
A-3	168.0—173.0	51.73	336	0.7617	1.4218	112.0
A-4	176.0—179.5	53.83	358	0.7622	1.4223	119.4
A-5	179.5—182.0	55.33	362	0.7630	1.4228	120.8
A-6	181.0—184.5	56.28	358	0.7634	1.4232	119.5
A-7	181.5—182.5	56.89	361	0.7636	1.4233	120.5
B-1	162.5—187.5	.....	353	.....	1.4238	.....
B-2	183.5—186.0	57.22	378	0.7647	1.4236	126.0
B-3	186.0—186.5	58.05	378	0.7651	1.4236	125.9
B-4	187.5—187.5	58.50	372	0.7655	1.4238	123.9
B-5	187.5—190.0	58.83	358	0.7660	1.4243	119.2
B-6	189.5—188.5	59.11	380	0.7660	1.4241	126.6
B-7	189.0—193.0	59.35	369	0.7660	1.4246	123.1
B-8	193.0—194.0	59.77	369	0.7660	1.4244	123.
B-9	194.0—194.0	60.32	378	0.7666	1.4246	126.
B-10	196.5—194.5	60.67	379	0.7671	1.4247	126.2
C-1	176.0—194.0	57.00	349	.....	1.4239	.....
C-2	194.5—200.0	60.73	387	0.7676	1.4249	128.9
C-3	200.0—199.5	61.11	388	0.7676	1.4251	129.3
C-4	197.5—199.0	61.44	374	0.7674	1.4249	124.6
C-5	198.0—202.0	61.89	389	0.7680	1.4254	129.8
C-6	199.5—204.0	62.28	385	0.7680	1.4251	128.2
C-7	204.5—205.5	62.67	386	0.7685	1.4259	128.7
C-8	205.0—206.0	62.95	367	.....	1.4259	.....
C-9	205.0—207.5	63.06	382	0.7690	1.4262	127.3
C-10	207.5—207.0	63.17	394	0.7690	1.4263	131.4
D-1	161.5—204.0	.....	...	.....	1.4221	.....
D-2	202.5—208.5	62.06	399	0.7701	1.4258	132.7
D-3	208.0—212.5	63.17	408	0.7701	1.4262	135.8
D-4	211.5—211.0	63.50	418	0.7697	1.4264	139.3
D-5	211.0—211.5	62.22	400	0.7714	1.4264	133.0
D-6	211.5—212.5	64.33	423	0.7713	1.4268	140.7
D-7	212.5—219.0	64.55	417	0.7718	1.4274	138.8
D-8	219.5—219.0	64.89	416	0.7720	1.4276	138.5
Res-1	220.0—219.5	.....	...	.....	1.4266	.....
Res-2	219.0—224.0	65.11	406	0.7729	1.4279	135.1
Res-3	220.0—221.0	65.28	415	0.7720	1.4280	138.3
Res-4	217.5—223.5	65.50	425	0.7733	1.4282	141.4
Res-5	222.5—224.5	65.67	416	0.7733	1.4283	138.5
Res-6	226.5—227.0	65.89	416	0.7742	1.4286	138.4
Res-7	222.5—222.5	66.00	433	0.7761	1.4292	143.8
Res-8	219.0—223.5	66.28	448	0.7757	1.4294	149.0
Res-9	217.5—223.0	66.61	460	0.7766	1.4296	152.9
Res-10	223.0—229.5	67.11	450	0.7773	1.4298	149.4
Res-11	229.5—232.5	67.84	460	0.7789	1.4302	152.6
Res-12	232.5—	68.17	467	0.7792	1.4308	155.0

Conclusions

The evaluation of the data presented herein allows the following conclusions:

1. The lower melting fractions probably consist principally of normal paraffins—the higher fractions definitely contain other compounds in addition to the normal paraffins.

2. The wax fractions studied appear to consist solely of paraffinic hydrocarbons, but naphthenic compounds may be present.

ACKNOWLEDGEMENT

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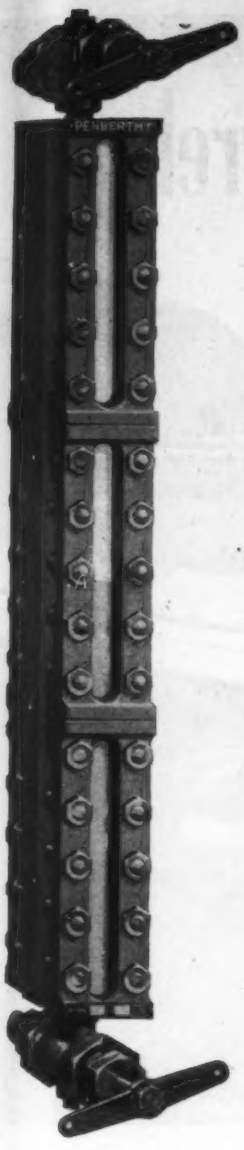

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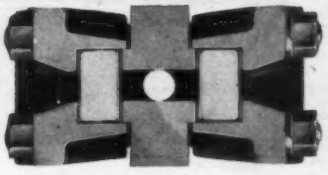

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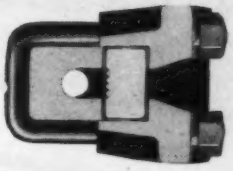
Used to observe color and density of liquids under high pressures, and/or temperatures. Construction is exceptionally rugged . . . . similar to Reflex types.



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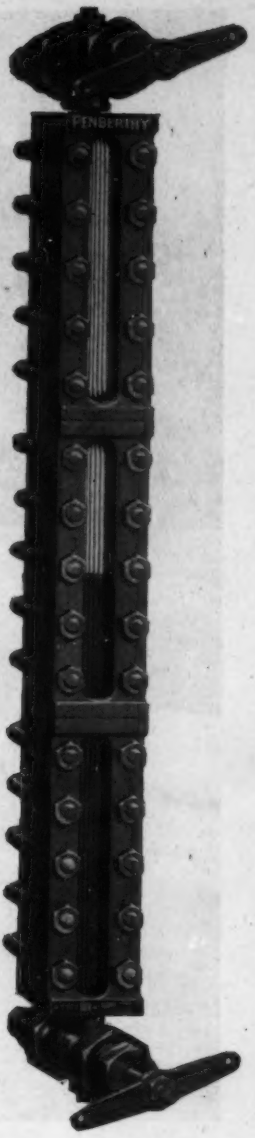
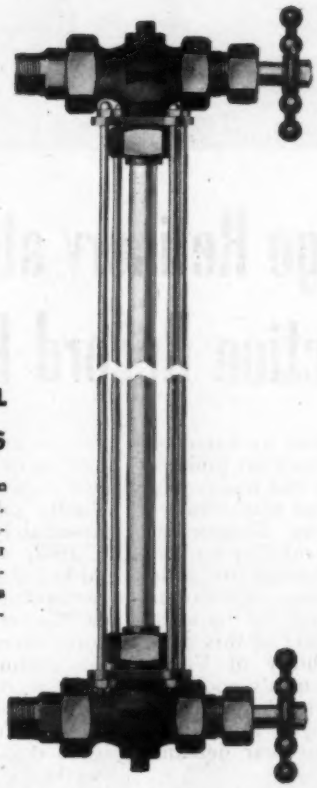
DROP FORGED STEEL LIQUID LEVEL GAGES

Liquid shows black — empty space shows white. Preferred wherever liquid level must be easily and positively visible . . . and when liquids are under high pressure or at high temperature.





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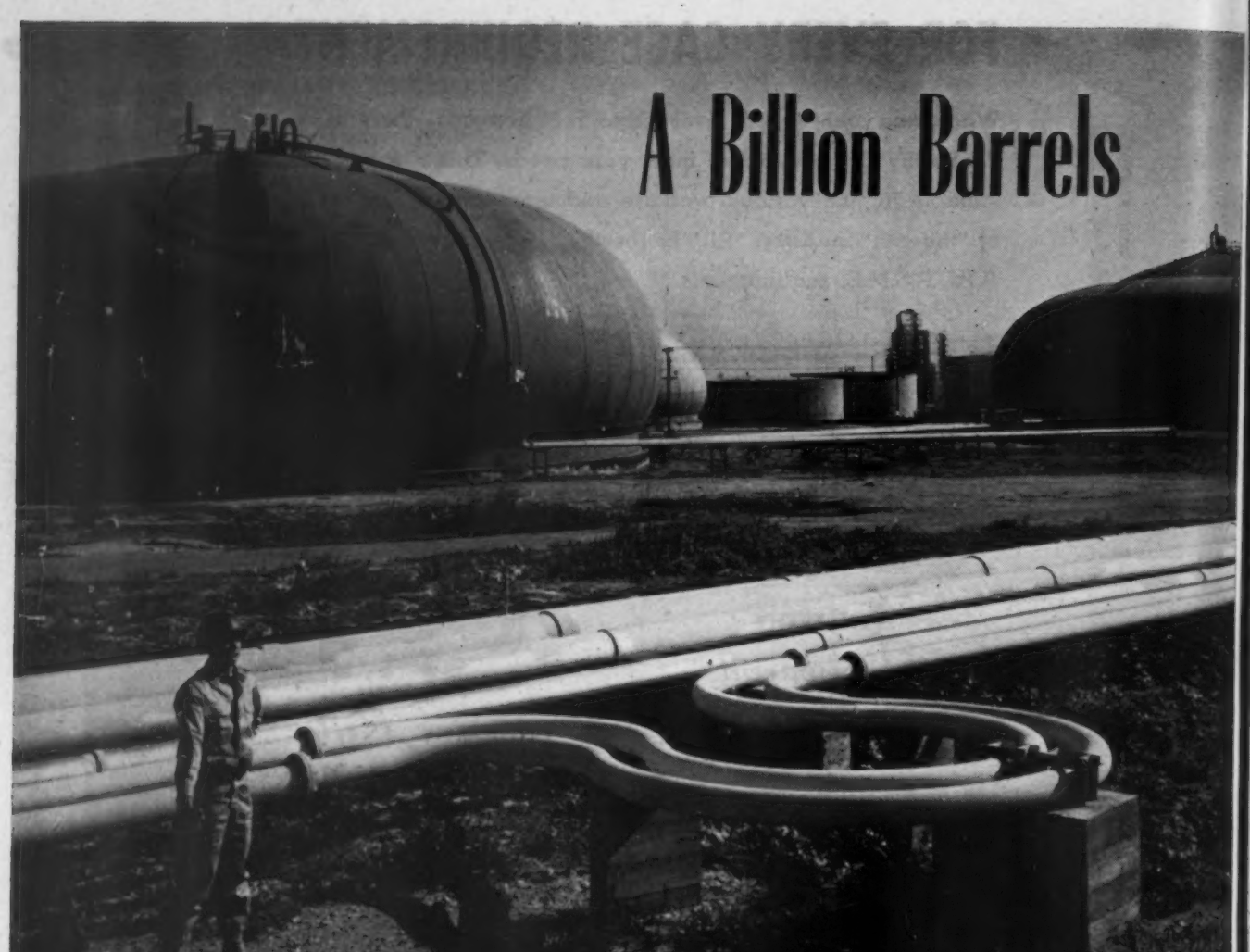


This soldier guarding the tank farm and loading lines at the Aruba plant of Lago Oil & Transport Company is on the only spot on the Western Hemisphere where a refinery or other industrial plant has 'been attacked by an enemy in this war.

Enlarged Lago Refinery at Aruba Makes High Production Record During War

ON A TINY coral island in the Caribbean, 6500 employees of probably the most blacked-out and isolated American war plant paused March 15 to celebrate a production achievement. They will process the billionth barrel of crude oil at the refinery of Lago Oil & Transport Company, Ltd., a subsidiary of Standard Oil Company (New Jersey), located on Aruba in the Dutch West Indies.

Aruba refinery has been operating 16 years. During war it has increased production while under constant threat from enemy subs, one direct attack, and many handicaps of nature.

Congratulatory messages were cabled to the workers by Under Secretary Patterson of the War Department, Admiral Carter of the Navy, Petroleum Administrator Ickes and other high government and military officials.

Aruba was described by Standard Oil Company (New Jersey) officials as a mere dot of an island lying off Venezuela, without fresh water, large trees, vegetables or any other pastoral aspects of nature. Nearly every basic commodity of living must be imported by some of the steady stream of empty oil tankers returning from the home and war fronts for more of Aruba's refined petroleum.

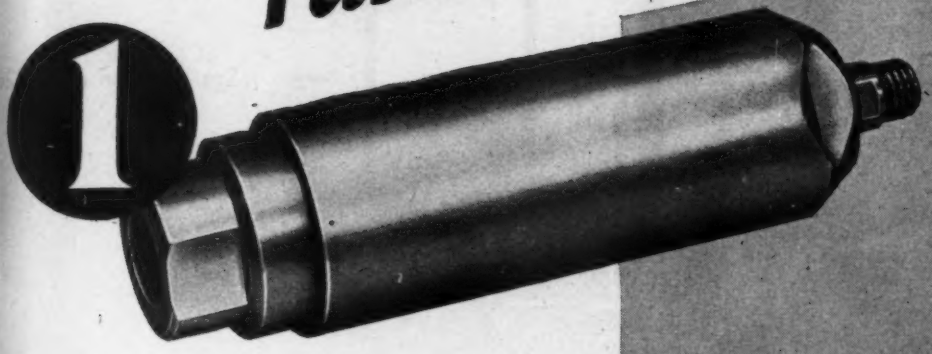
Crude oil from nearby Venezuelan fields is transported to Aruba by tanker, there to be processed through its stills and cracking units, thence to fan out to all parts of the world by tankers. Company officials point out in this connection that the availability of Venezuelan crude, and Venezuela's cooperation with the United Nations' war effort, have been major factors in the ability of the latter to meet the war demand for oil products.

In addition to the exceptional natural limitations, Lago's workers, which include some 600 Americans, have continuously refined 100-octane aviation gasoline and other war products under a strict dimout which at any moment must become a total blackout. The latter actually prevailed during nine months immediately after the night of February 16, 1942, when a German sub surfaced and began shelling the island and harbor. One tanker sunk; another was disabled; but the refinery escaped unscathed. Aruba then donned a coat of battle gray —its gleaming silver towers and storage tanks were repainted; all lights were totally hidden.

The strategic importance of the established refining facilities on Aruba when war broke has made its modern oil refinery of focal importance to the entire war program, and it has been producing at capacity since before Pearl Harbor. Essential new supplementary units were put into operation nine months after construction had been started. New war requirement quotas have been passed continually.

More Aruba Plant Pictures on Page 128

RECIPE FOR *Faster Tube Cleaning-*



1

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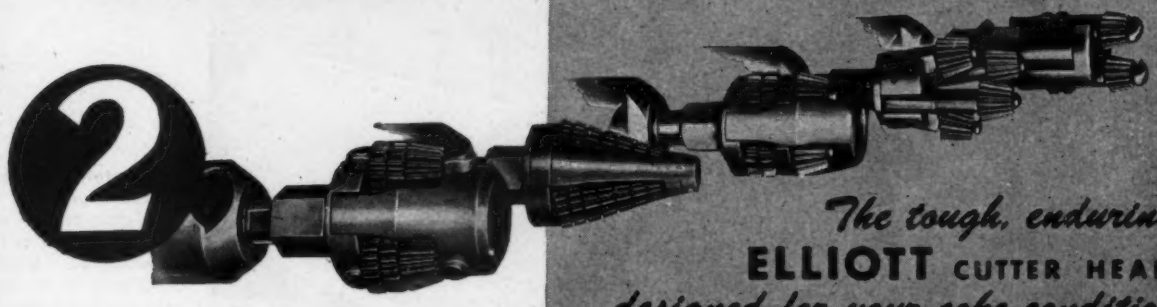

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The time-saving, quick-acting
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that works like an accelerator

Add to these ingredients, the Elliott Automatic Lubricator, and Elliott operating hose and couplings, and find new freedom from cleaner failure and delays, and new satisfaction in a fast job, well done.

If not sure of the right Elliott cutter-motor combination for your coke condition, call upon the glad cooperation of the Elliott tube cleaning engineer in your territory. Write us.

New tube cleaning bulletin Y-18 just published. It's a new kind of fact-giving manual. It's valuable. Mailed at your request.

Y-234

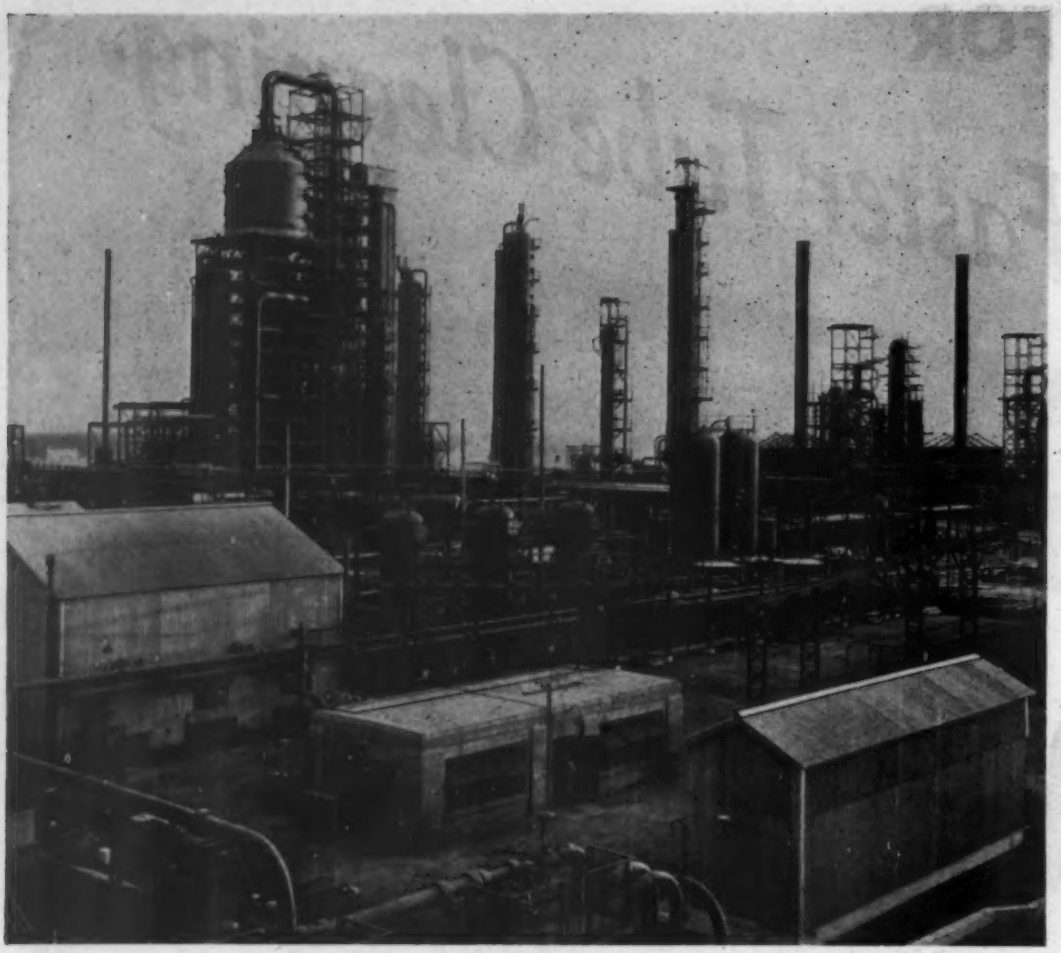
ELLIOTT COMPANY

Tube Cleaning Headquarters

SPRINGFIELD, OHIO • DISTRICT OFFICES IN PRINCIPAL CITIES

A Billion Barrels

(See story on page 126)



The catalytic cracking and attendant units at Aruba are evidence of the enlargement of facilities, after the war had multiplied hinderances to operations, on an island where the shipping accessibility alone is reason for its location.

This elevated view of part of the plant and tank farm shows more of since-the-war installations for producing high-octane gasoline at the Aruba refinery of Lago Oil & Transport Company. This plant processed a billion barrels of crude in 16 years of operation.

The odds are 4000 to 1

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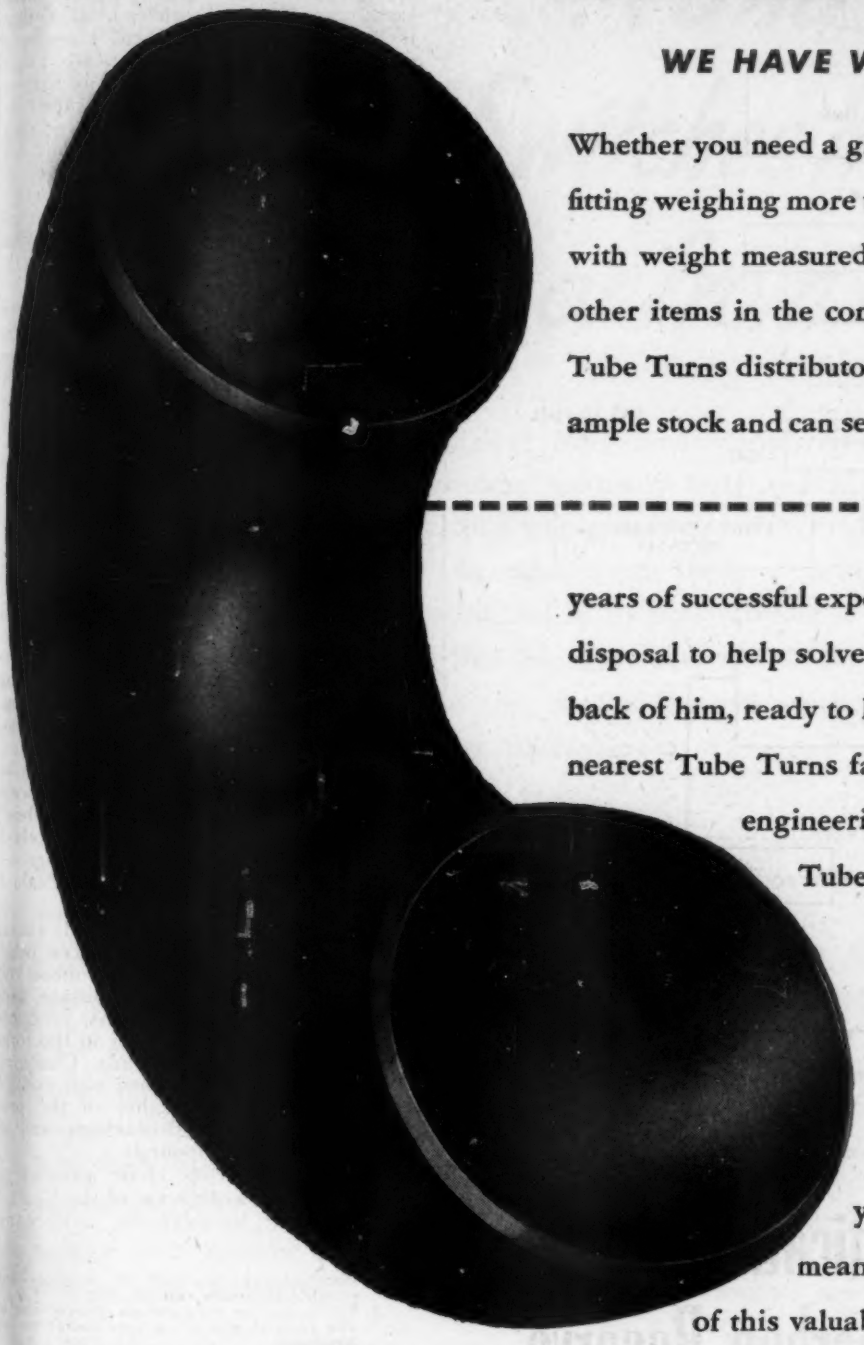

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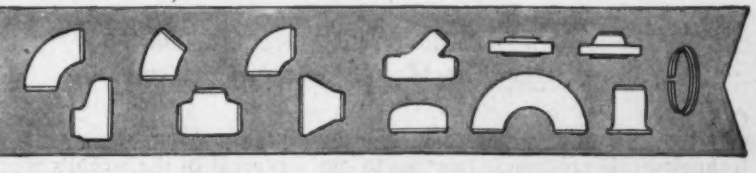

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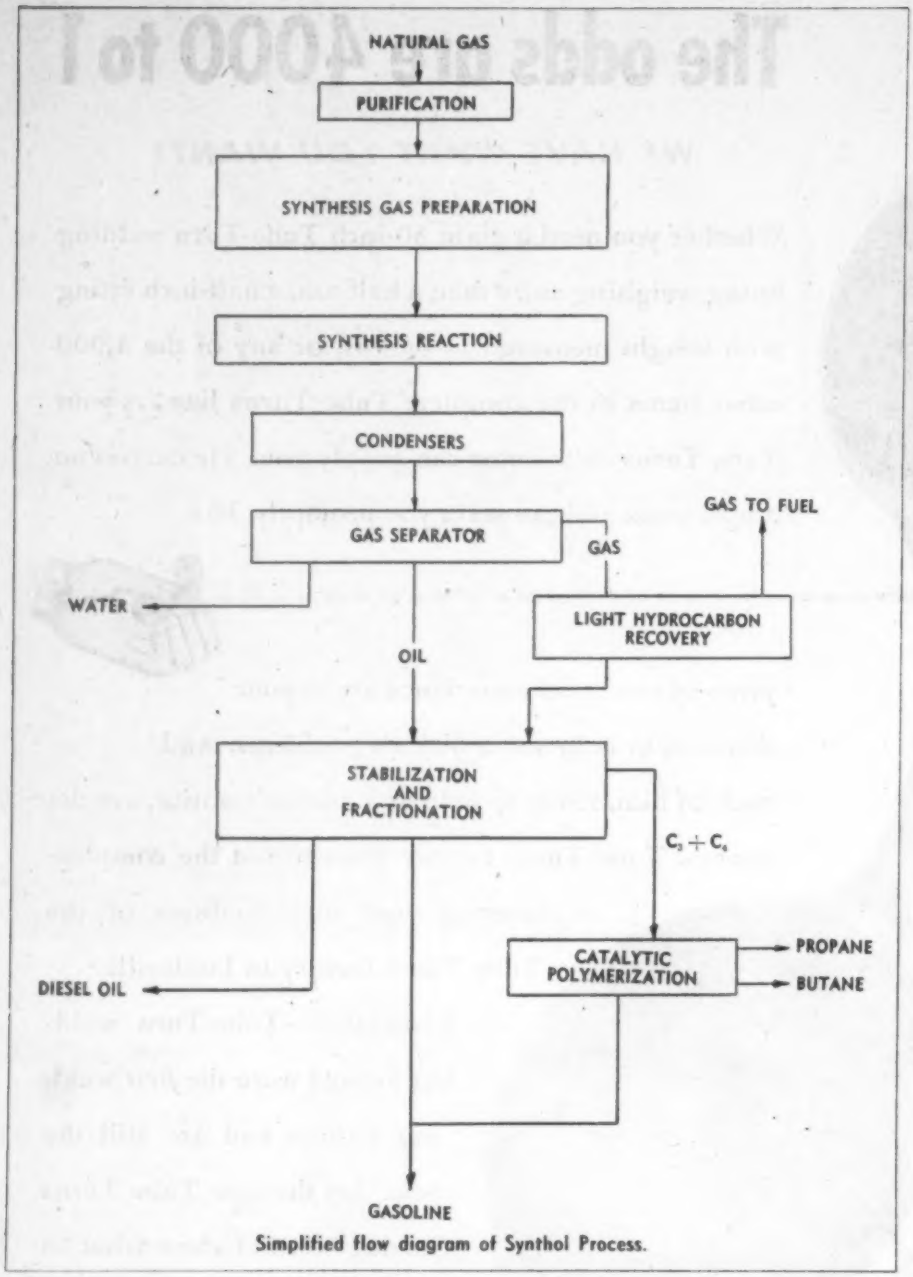

Simplified flow diagram of Synthol Process.

Natural Gas Liquefication Process Enhances Hydrocarbon Reserve

PAUL RYAN, Vice President,
The M. W. Kellogg Company

THE war-stimulated development of technological processes has made no greater advance than in the petroleum industry. Utilization of various peacetime gaseous by-products from a petroleum refinery to make chemical components of aviation gasoline, synthetic rubber, intermediates, etc., has accelerated conversion of the average petroleum refinery into a potential postwar chemical plant.

Excessive drafts on the petroleum reserves to satisfy wartime demands have emphasized that the United States has been providing annually more than 70 percent of the world's supplies of petroleum from 15 percent of the proven oil reserves and from 25 percent of the world's potential oil reserve. Wartime cries of "shortage of oil" arose, and some fears were stimulated that wartime demands would produce exhausted postwar petroleum reserves.

Petroleum is an exhaustible and nonreproducible resource. Competent authorities have estimated that with increased drilling activity within continental United States more petroleum reserves will be available; these will push farther back to date of ultimate exhaustion of this country's petroleum reserves. Long before that date, however, these same competent authorieies indicate that technological processes will have been developed to render economically available the hydrocarbons present in natural gas, in oil shale, in asphalt sands, in coal, and in other forms. Compared with total past petroleum production and future petroleum reserves in this country, hydrocarbons from natural gas more than equal such oil reserves, from oil shale they exceed four times, and from coal they exceed sixty times this tremendous amount.

Technical research, stimulated by the war, has accelerated the tempo of prewar research on the conversion of these various natural resources into usable hydrocarbons. Principal among these has been the development of the Synthol process for manufacturing liquid hydrocarbons and other products from natural gas. The following data are pertinent to a consideration of this process:

The Process

1. Since 1935, The M. W. Kellogg Company has conducted research on this process. In 1937, data on the Fischer-Tropsch process were obtained by the company, and during the intervening years it has pioneered the development of this work into commercial-plant design.
2. As an answer to the wartime cries of "shortage of oil," this Synthol process will produce motor gasoline (75 "clear" octane CFR-M) for approximately 5 cents per gallon (including 10 percent depreciation) from natural gas valued at 5 cents per 1000 cubic feet.
3. Besides gasoline as outlined above, this Synthol process produces other liquid hydrocarbons, e.g., diesel oil (90-100 diesel index) and butane, and, under controlled conditions, produces various chemical products in the form of oxygenated compounds. Changing the operating conditions will control the quantity and quality of the production of the hydrocarbons and of the chemical compounds.
4. An accompanying chart presents a simplified flow-diagram of the Synthol process. It involves the following steps:
   a. Purification — removal of sulphur and other deleterious compounds.
   b. Synthesis gas preparation—conversion of the natural gas to carbon monoxide and hydrogen.
   c. Synthesis reaction—in the presence of the selected catalyst, under controlled conditions, conversion of the gas to the desired hydrocarbons and the desired chemical compounds.
   d. Condensers—condensation of the various products to liquid form.
   e. Gas separator—separation of the oil layer containing the liquid hydrocarbons from the water layer containing the chemical compounds, and separating and recovering the light gaseous products.
   f. Stabilization and fractionation of the various liquid hydrocarbon products into gasoline and diesel oil.
   g. The liquid chemical compounds are separated and recovered.
5. A complete Synthol plant to produce a large volume of liquid hydrocarbons, it is presently estimated, would have a pay-out-time of approximately eight years. A combined Synthol and chemical plant, it is presently estimated, would have a pay-out-time of approximately three years. This acceleration in financial return is due to increased

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Cooper-Bessemer's new and sensational development, the gas-or-oil diesel, not only makes virtually any combustible gas an ideal fuel, safe and entirely practical, but the downright simplicity of switching from one fuel to the other is in itself a remarkable feature. It offers revolutionary possibilities in its application to numerous power requirements throughout the oil, gas, and petro-chemical industries.

Here are several factors that will have particular significance to engineers and operating officials:

1. As illustrated, complete conversion from gas to oil fuel or vice versa actually involves only the partial turn of a single control.
2. Fuel change-over is accomplished instantaneously, without shutting down and *at full load.*
3. Fluctuating or insufficient gas supply can be compensated for by the simultaneous use of *both* fuels in any desired, readily controlled proportion.
4. Gas-oil proportion or complete fuel change-over may be *automatically* controlled to conform exactly with fuel supply and load requirements, entirely eliminating manual action.
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6. Since the thermal-efficiency of a Cooper-Bessemer diesel is so much higher than that of the best gas engines of the electrical ignition type, *20 to 25% less fuel* will be required for a given power output. Or, correspondingly more work can be done with a fixed or limited gas supply.

The dual fuel feature is applicable to the complete range of standard Cooper-Bessemer diesel types and sizes. Thus these engines, all the way from 50 to 1800 hp, can now burn gas or any desired combination of gas and oil with full diesel thermal-efficiency. Perhaps the engines you'll be needing should embody this new development. The nearest Cooper-Bessemer office will welcome a discussion with you.

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values of the chemical compounds over the values of the hydrocarbons.

6. In all these calculations the cost of 5 cents per gallon of gasoline from the Synthol process includes no value for chemical compounds and is independent of the investment and profit from the operation of the chemical plant.

7. The company's analysis of Synthol economics seems to indicate:

a. The plant should be located close to large gas reserves. Approximately 11,000 cubic feet of natural gas are required to produce 1 barrel of liquid hydrocarbon product. Foreseeable gas reserves should at least equal 10 years' plant requirements.

b. The plant should be located on water to achieve lowest cost transportation for both kinds of products—hydrocarbons and chemical compounds. Location on the Gulf Coast, providing water transportation to the industries of the East Coast and to the upper Mississippi Valley, would be quite advantageous.

c. Undoubtedly, postwar conservation regulations of the Texas Railroad Commission, and of other states, will enforce gas-oil-ratios. Continued satisfactory operation of a Synthol plant, requiring large volumes of natural gas, would necessitate the location of the Synthol plant contiguous to a presently operating or newly built oil refinery to handle the large quantities of oil produced under these gas-oil-ratios.

d. The plant should be operated in conjunction with a petroleum refinery to assure constant availability of skilled technical personnel for general supervision, and for joint utilization of existing refining and distributing facilities.

e. Present research indicates that operating costs for the separation and the recovery of the chemical compounds are low, regardless of the assumed initial value, for accounting purposes, of the by-product stream from the manufacture of the liquid hydrocarbons, which, in turn, becomes the raw material for the recovery of the chemical compounds.

f. While the total volume of oxygenated compounds produced from any one plant constitutes a small percentage of the total prewar, and estimated postwar, consumption of similar products by the chemical industry, the operation of many such plants by the petroleum industry might saturate the market for such chemical compounds and would adversely affect the profitability of such plants.

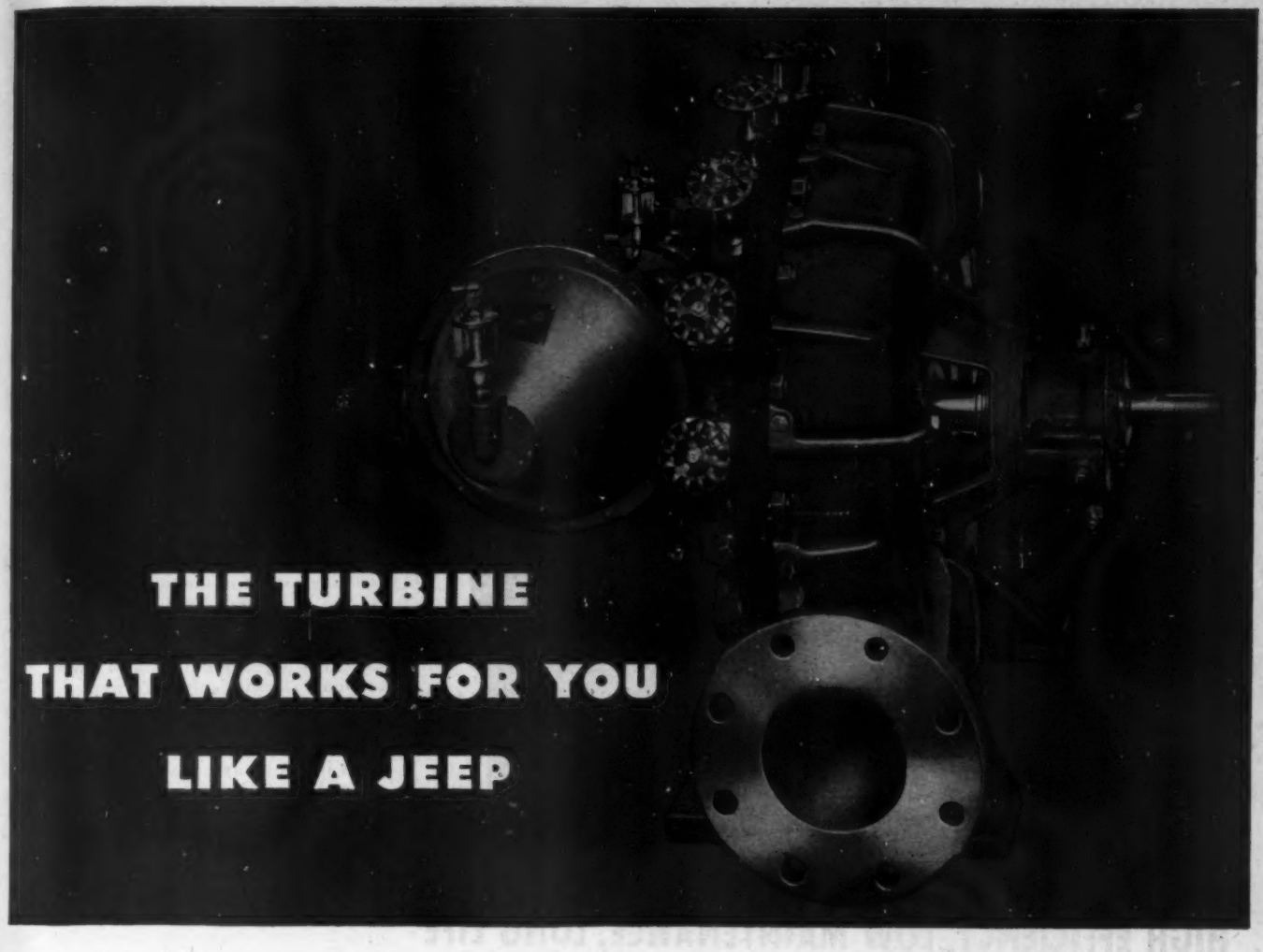
Evaluated under present economic circumstances, the factors of investment, of gas reserves, of cheap transportation, of marketing considerations, and of understanding of chemical industries, will create limitations which will undoubtedly serve to caution the wide-spread participation by many oil companies.

The Synthol process can have unusual economic advantages for petroleum companies qualified to use it effectively.

Chemicals

The Synthol process is another milestone in the inevitable union of some of the interests of the petroleum industry with some of the interests of the chemical industry. This process not only assures the economic availability of large volumes of gasoline and diesel fuel, so essential for the industrial and social standard of living in this country, but it also provides means for the mutual intelligent and profitable development of the petroleum industry's resources with the successfully functioning facilities of the chemical industry.

Petroleum companies now occasionally consider whether they "will enter the chemical industry." As Dr. Robert E. Wilson, chairman of the board of Standard Oil Company (Indiana), recently indicated, the petroleum industry is already deeply in the chemical business. Wartime production of toluene is over five times the prewar total combined production of phenol, aniline, and toluene, all used as synthetic organic chemical compounds. Dr. Wilson further pointed out that the wartime production of butadiene is over 27 times the prewar production of phenol, and the petroleum industry's production of ethyl al-



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You'll see Coppus "Blue Ribbon" Steam Turbines on many nationally-known types of equipment. Manufacturers of that equipment know the quality that is represented by the Coppus "Blue Ribbon" — more than 85% of all orders since 1937 has been repeat business.

Select the right size of Coppus turbine for any job that calls for "jeep duty". Like all Coppus "Blue Ribbon" products (blowers, ventilators, gas burners, etc.), they are made to extremely close tolerances with accuracy controlled by Johansson size blanks. Before shipment, every turbine is dynamometer-tested.

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In ordinary cyclones, this dust circulates under the top plate, finally dropping by gravity through the upward, rotating gas stream of the "double-eddy" current. Thus, in its passage to the dust discharge outlet, the "fines" become re-entrained in the gas flow and are partially lost through the gas outlet.

This exclusive feature of the patented Buell (van Tongeren) cyclone is a prime factor in Buell's well-known high recovery efficiency.

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cohol, also used in the production of synthetic rubber, is almost half the total prewar consumption of ethyl alcohol for all purposes. And over half of our 100-octane gasoline is made from the newly developed chemical engineering union of two hydrocarbons by the petroleum industry. The petroleum industry is very definitely in the chemical industry.

The petroleum industry fundamentally makes and distributes products which are manufactured on a mass-scale, which have broad specifications and universal use, which have high rates of consumption, which are sold through hundreds of thousands of retail outlets on narrow margins at a low price to consumers who have no facilities for storage and are "high-frequency" repeat customers.

Financial Comparisons

The chemical industry on the other hand has, up to now (except a few products in broad mass consumption), made comparatively small volumes of individual products which conformed to rigid specifications for particular and limited uses, which were sold at long margins of profit and at high prices to comparatively few customers who contracted for purchase infrequently and who had adequate facilities for storage.

Besides, financial comparisons show that the chemical industry does 80 percent of the dollar business of the petroleum industry and makes 125 percent of petroleum's net income. Operating profits of chemical industry's larger companies annually average over 30 percent and net income averages 20 percent; the petroleum industry's larger companies are fortunate to fare half as well. Wartime chemical volume is over four times prewar; the desire by normally "marginal" companies in the chemical industry to perpetuate their postwar economic existence will further intensify postwar competition in the chemical industry.

On almost every characteristic of the distribution and marketing of their products, the petroleum and the chemical industries have been markedly dissimilar. This dissimilarity urges the petroleum industry to give serious consideration to those successful and profitable techniques of marketing chemical products which have been so long established by the chemical industry. Any destructive competition between the two industries undoubtedly would produce unfortunate repercussions for all concerned. Historic long margins and high profits on chemical products would offer chemical companies unusual leverage in successfully coping with postwar competition, particularly in the marketing of those broadly available chemical compounds unprotected by sound patent positions.

Just as automotive companies have made tanks, boats, and airplanes during the war, just as every other industry has branched into the manufacture of allied products essential to the war, so too, the petroleum industry has been stimulated to accelerate the development of processes for the manufacture of wartime chemical products. The problem facing the petroleum industry is "We have proven we can make these new chemical products during war; during peace, can we market them profitably?"

The Synthol process assumes a dual responsibility; it offers an economical competitive means of obtaining gasoline from natural gas, as an substitute source

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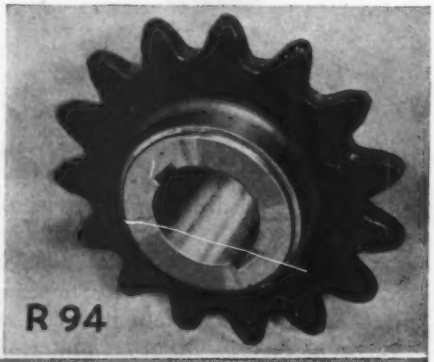
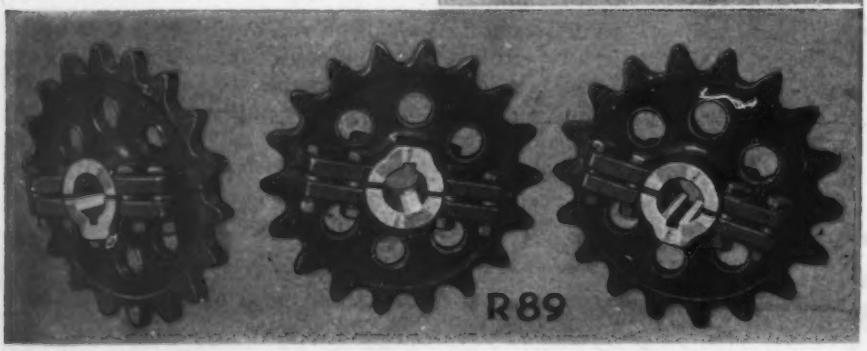
Too, they impart longer life to transmission chains by taking a smooth polish on the tooth faces after a short time in operation; the result of the valuable work-hardening characteristic of manganese steel. Naturally, Amsco sprocket wheels have a service life substantially greater than wheels of ordinary materials.

Amsco sprockets for oil field use were first introduced over 20 years ago. The splendid performance of these sprockets and their quickly proved economy led to the introduction in rapid succession of Amsco manganese steel sheaves for traveling and crown blocks, catheads, drill stem bushings and clutches; in every instance with savings in drilling costs. It didn't take oil field men long to realize that manganese steel castings were essential for economical operation.

Send for Bulletin 244-P, "Manganese Steel for Oil Field Service."



R-94 Manganese steel drilling rig sprocket, 15 t., 14.79" p.d., wt. 108 lbs. Bore, hub ends and keyways machined.
R-89 Split sprockets for oil well drilling rig, 18 t., wt. 235 lbs. Bore, keyway and hub ends finished.



Amsco-Nagle Centrifugal Pumps for handling coke breeze are described in Bulletin 940.

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for petroleum, and simultaneously it provides an effective and economical source of some chemical compounds.

Locations

This process can have a present appeal to those companies which have adequate gas reserves located close to oil refineries, contiguous to economical transportation and whose managements are realistically mindful of the economic problems, not only of manufacturing chemical compounds, but also of their profitably distribution.

The process also can appeal to those companies in the industry who by their experience have matured their thinking on the distribution and marketing of chemical compounds and who consider the Synthol process an additional source of economical chemical compounds, while they consider the hydrocarbons, as by-products, whose production would be utilized whenever their own company conditions of crude-oil supply and refinery activity would warrant.

The history of industrial development shows that wars have accelerated the activities of the inventive genius of each nation to make weapons to destroy the enemy; history also shows that wartime unrealistic "romancing" about the peacetime utilization of these same inventions always creates postwar problems.

Bearing in mind the necessity for realistic appraisal, the Synthol process is no panacea, but it does present for some oil companies interesting postwar possibilities for the economic and profitable development of new uses for an old natural resource.

Secretary Ickes Cracks At Estimates of Reserves

Taking a crack at the various estimates of oil reserves that are made from time to time, Administrator Ickes told newsmen that, "in order to have an encouraging statement of reserves now, the experts just get together and mark up the statement of known reserves, so one day we may have 14 years' supply and the next day 28 years' without a barrel of oil actually moving."

At the same time, Ickes admitted, "we can't keep up a 5 million-barrel daily production indefinitely."

"The time will come when we will be an importing country and not an export country," he added, "but that doesn't mean we will not have a market for every barrel of oil we produce here."

Ickes disagreed with those who foresee a sharp drop in demand for oil after the war with a prolonged period of slow recovery, expressing the belief that the decline will be neither very great nor very long. He based his opinion on the demand for automobiles which will come at the end of the war and anticipated development of civilian air power.

General Petroleum and Gilmore Consolidate

Consolidation of Gilmore Oil Company and General Petroleum Corporation, both of Los Angeles, has been announced, the consolidated organization to continue under the name and management of General Petroleum Corporation. C. S. Beesemyer, president of Gilmore Oil Company, has been added to the General Petroleum Corporation's board of directors.

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Petroleum's Magic Towers

WILLIAM R. BOYD, JR.*

President, American Petroleum Institute
Chairman, Petroleum Industry War Council

FIGHTING and winning two separate, all-out wars at the same time is a task that only a few years ago was simply beyond belief. Each of the wars which now engage our every effort make the first World War look like a skirmish. To appreciate that fact one only has to compare the number of our men under arms; the size of our Navy; the strength of our Air Force; the cost to date; the distances to battle and the starkly significant casualty lists, with the same facts of the last war. The comparison will disclose a trend that portends a world disaster so terrible as to be almost beyond comprehension if another war comes. Savagery and slaughter will surely be brought our own cities and villages if the four dread horsemen ride again.

Indeed, such might have been our own hard experience in this war if the great oil fields of California and Texas and the other oil-producing areas of the nation had not existed to support our millions of warriors in the air, on the land and on the sea, and had not supplied the amazing flood of oil that has kept our mechanized might rolling steadily ahead to victory and peace. I find it especially gratifying that within only a few weeks I have had the opportunity to visit our two greatest oil producing states, California and Texas, and fraternize with so many of the men I know have made these two states the great and indispensable oil producing areas that they are. But, of course, it must be understood that when I pay tribute to these two states, I in no way intend to minimize the importance of the other oil-producing areas which also are making their proportionate contribution to the war program. In truth, every oil-producing state and refining area is contributing its utmost to the war effort.

* Before Wartime Conference of Pacific Coast District, Division of Production, American Petroleum Institute, Biltmore Hotel, Los Angeles, Thursday, March 29, 1945.

"Towers"

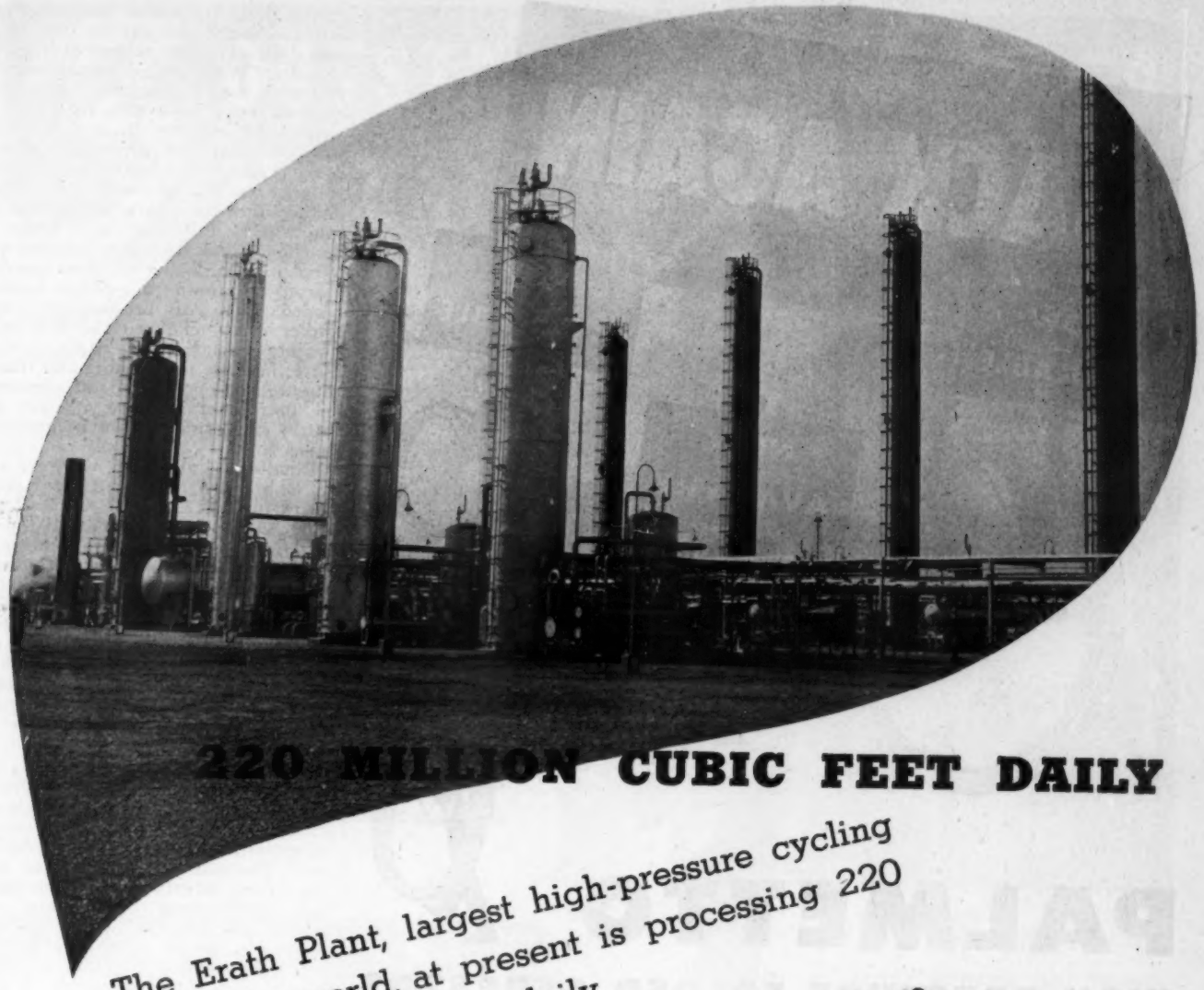
We haven't heard much about "towers" being prominent in the inception or conduct of war. And yet today we have thousands of towers scattered through our land that are the very essence of modern war. I refer, of course, to the host of oil derricks of all descriptions, from the grimy little timber tripod of our old shallow oil fields to the trim and clean-cut structural beauty of steel that provide the means whereby we bring our present deep oil wells into useful being. Without these towers our industry could neither have been born nor reared to its present huge stature. When I say towers, I refer also to those amazingly intricate symbols of modern alchemy, the pipe-laced compositions in towering steel that comprise the modern refinery which has outgrown its name. No longer is the term refining applicable to the elaborate chemical processes that accomplish the conversion of crude petroleum into a myriad hydro-carbon compounds, many of which are non-existent as such in the crude oil.

So, if the terms "wizardry," "alchemy" and "wondrous" are applied so frequently to these towers that initially wrest petroleum from the earth's embrace and then in different design act to refashion the teeming molecules in diverse ways to yield all manner of good and useful products as well as those that are terrible and destructive, is there not reason to name them petroleum's magic towers? And, from the standpoint of our own national existence what have these magic towers done for our country in this struggle for survival? Now that the curtain is inexorably and swiftly falling on the Nazi hordes in Europe, this seems to me a pertinent question.

Swaggering Nazi bullies, of the self-styled "master race," who once sneered at the "weakness of corrupt America" are already on the run. They have seen and felt the military might of the United States; they have been smashed and disorganized by the courage, the self-reliance and the individual and collective ingenuity of free Americans who have united to keep the production line busy and the home fires burning. In the Pacific, the treacherous Japs are getting foretastes of the retribution that is headed their way. Japan had no idea that the mightiest armada which ever sailed the seas could roll up to her very doorstep in little more than three years after Pearl Harbor. She, too, had no concept of America's industrial might or of the ability of the young warriors of this nation to make use of that power to its telling utmost.

A Leading Part

The Oil Industry has played a leading part, a vital part, in making our tremendous war machine possible. The American oil industry has performed stupendous assignments. Any one of them properly could be called an industrial miracle. Everyone knows our war machine could not have rolled without petroleum. And so I speak tonight



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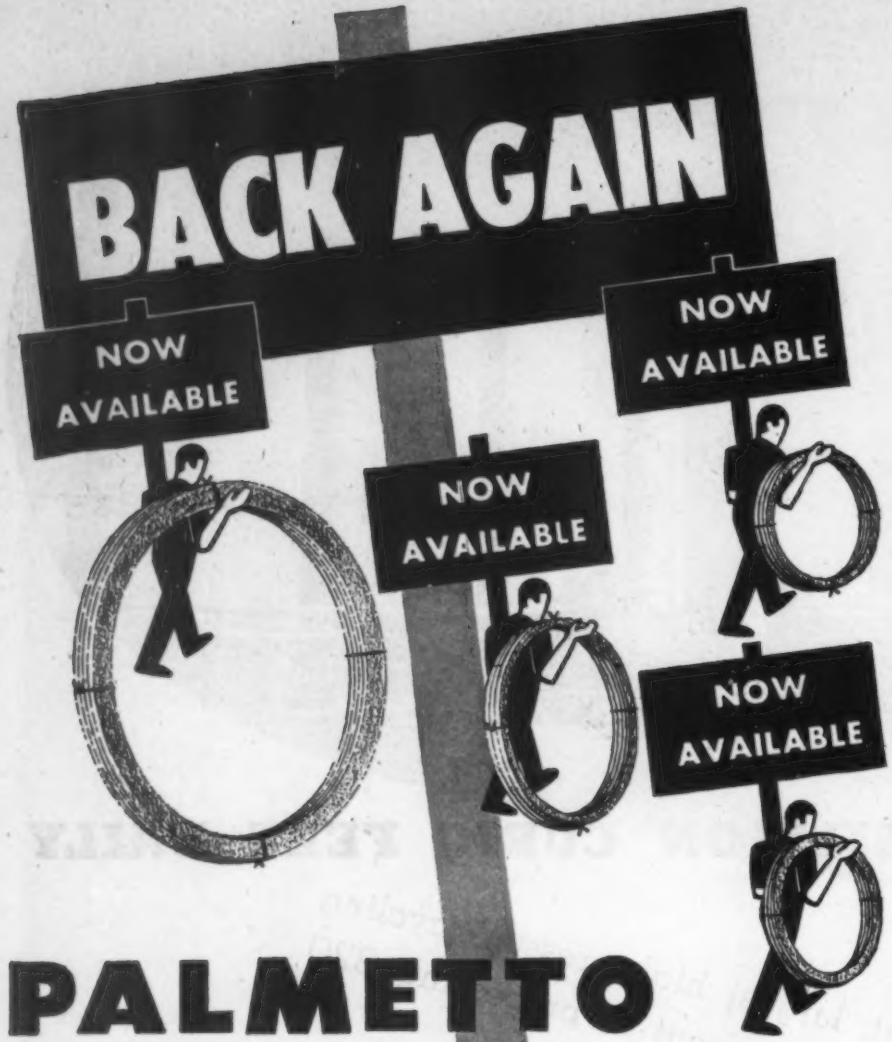

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on behalf of the entire American petroleum industry and say to our fighting men,—all of them, wherever they may be,—not "We are glad we are supplying you with the oil you need," but "Thank God we have been able to do it!" We have been able to do it for the very simple reason that when the call to the colors came, the petroleum industry responded with the same effective ingenuity that has characterized the fighting American soldier and sailor. We have been able to do it because petroleum producers spat on their hands and started oil coming out of the ground at record rates of production; because tanker crews endured the hell of submarine warfare and came back for more; because the refining and transportation divisions, indeed all elements of the petroleum industry at once united into a single giant team to get the job done.

Finally and above all, we were able to do it because of the magic towers of petroleum!

Let us, however, not dwell too much on what those magic towers mean to the war effort. That story is being written in the pall of smoke over Tokyo, Nagoya and Osaka, and in the twisted ruins of German factories and cities; in the jungles of Burma and in the mountains of Italy. Let us instead think about what these magic towers will mean to the United States of tomorrow and what they could mean to tomorrow's world.

Reshaping Molecules

No one man can be given credit for the reconstruction of the petroleum hydrocarbon as represented by new processes initiated and developed during the war. Thousands of men have contributed their talents to this, the outstanding achievement of modern science. Energized by the war, the various processes which take petroleum apart and put it back together in new and vastly improved forms have literally leaped from the laboratory to full-scale operation overnight. Important changes have been made in great new refineries while they were under construction. Today's aviation gasoline is only a distant relative to yesterday's and tomorrow's will not even know its own grandparents! Science is reshaping the petroleum molecules, one of nature's greatest sources of mobile energy. Our petroleum scientists are acting very much as if they were alchemists who have found the secret of transmuting base metal into gold.

Only a few short years ago, we thought of petroleum only as a source of light and lubrication. Then we found in it a means of propulsion and a fuel, an economical source of transportation and power. Remember, however, that when the War Department bought three cars for the use of officers in Washington in 1899 they ordered extra attachments so the "horseless carriages" could be pulled by mules in case the engine did not work. That was a more conservative War Department than today's which decided to move into Greenland one day and asked for fuels and lubricants that would work up there the next—and got them.

The automobile industry before the war constituted our principal outlet for petroleum. But no automobile industry existed, nor could have existed before the discovery of petroleum. From 1900 to 1942, when the manufacture of automobiles was halted by the war, the American automobile industry had

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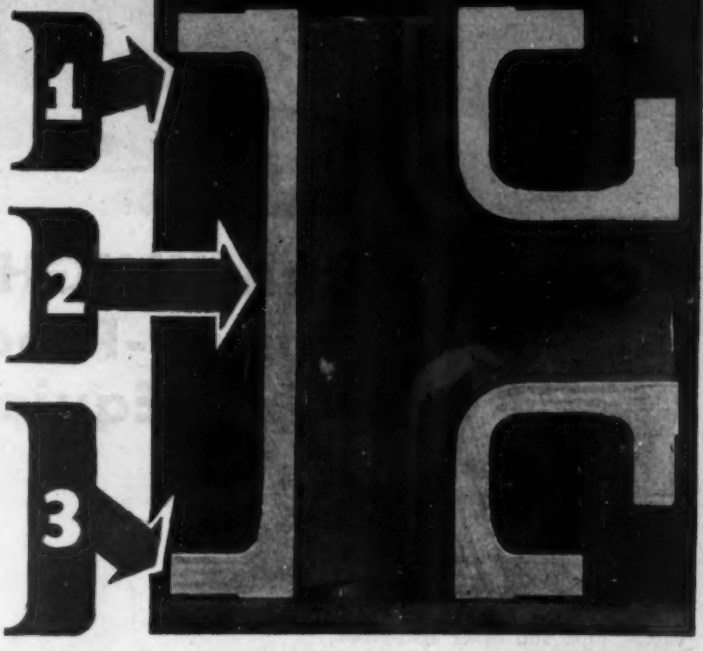

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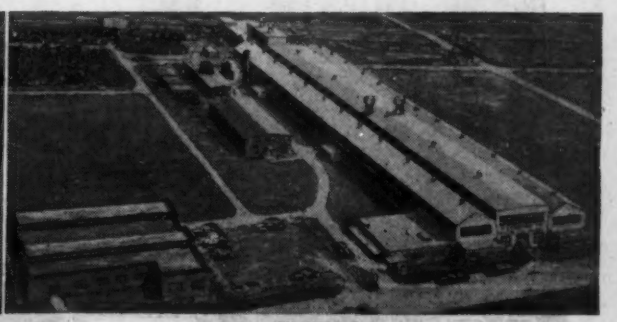

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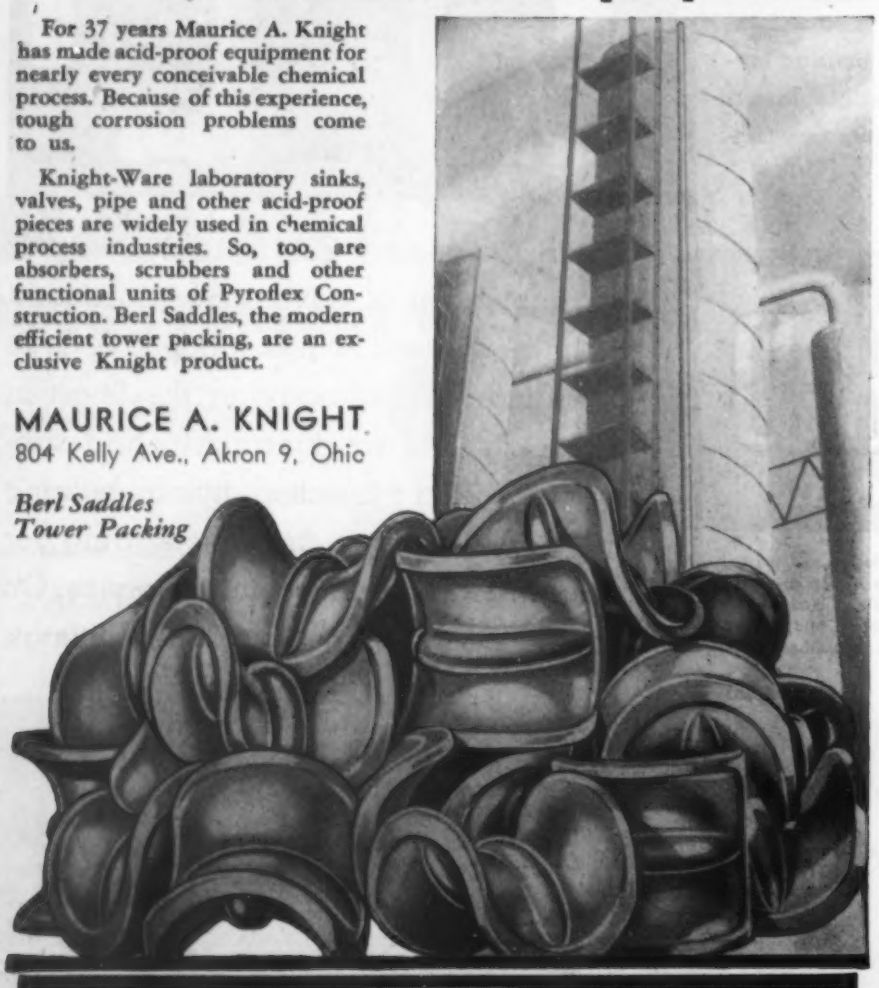


KNIGHT-WARE
CHEMICAL EQUIPMENT

turned out roundly 69 million cars with a total wholesale value of 44 billion dollars! The rubber and oil industries have grown in proportion. Whole new vistas of trade and commerce and individual opportunity have resulted from the team of petroleum, rubber and the automobile.

I hesitate to prophesy the extent of the future of the airplane. It is likely much greater than any of us can envisage. It is certain that thousands of persons will be employed after the war in some phase of aviation. Again, a new industry has been born, based upon petroleum!

Petroleum as a source of chemical products is not entirely new. Its products and by-products have been entering American homes and industries for many years, but to a degree usually unappreciated by either the industrialist or the householder. The science of hydrocarbon chemistry has already grown rapidly and its ultimate place in our lives is beyond the comprehension of any of us.

Seeds of New Industries

The new science of hydrocarbon chemistry undoubtedly has the seeds from which most new industries will spring up in this country after the war. Not the day after, of course, nor the week after, but within the decade. The vast majority of those which we can now foresee are not the type which will drive an established activity out of business to be replaced by another, but are new services which will make for better living for all. The petroleum scientist insists he is merely standing on the threshold of what he believes is capable of accomplishment.

During the war we have engaged in many extra-curricular activities. The development of synthetic rubber in this country, for example, reads like a Jules Verne novel. Who would have suspected by 1945 synthetic rubber, derived to a great extent from petroleum, would exceed a production of more than a million tons yearly? I predict, though I am fully aware of certain dissents and their reasoning, that a great new American industry has been established and that it will endure after the war.

These same magic towers are bringing like improvements to fuels and lubricants. That amazing story must await the end of the war, yet it is no secret to you, of course, nor to the American people generally that superaviation fuels are being made and lubricants perfected that will withstand any known range or vagary in atmospheric temperatures. The American motorist will have little use for these extremely high-grade products, but because we have learned to make them, he will have greatly improved gasoline and lubricants for his requirements. The automobile of not so many years hence will be a marvel of the combined skills of the automotive engineer and the petroleum scientist. Farms, homes and industries in general, too will profit.

Way Must Be Kept Open

I suggested that we dwell on what the magic towers of petroleum would mean to the United States of tomorrow and what they could mean to tomorrow's world. The blueprint, it seems to me, is clear and simple. To reap the benefits of petroleum, the way must be cleared and kept cleared to produce it, to process it, to transport it and to distribute it. The way must be kept

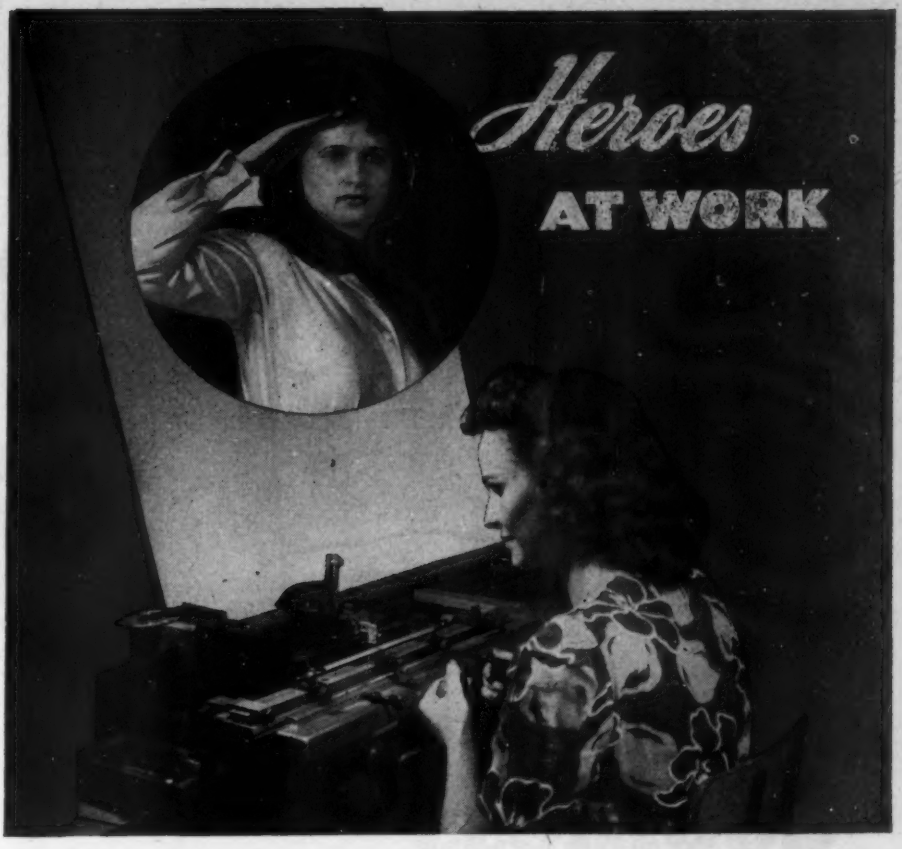
cleared for individual enterprise, individual achievement and individual reward. The path must be kept open for constructive competition between men and organizations to the end that each man's mind is whetted against the other man's abilities. If the world wants petroleum, artificial barriers must not be erected by governments to prevent men from seeking it wherever it may be found, and from profiting from their discoveries.

From some things we hear one would never think that industries, like governments, are run by human beings. Some seem to think that individualism, somehow, is not to be trusted; that imagination and initiative and daring are bugaboos of which to beware. Well—if that be true, we would not have over 400,000 producing oil wells in the United States. Indeed, perhaps no one would have drilled the first one yet! We would not have your tremendous California oil industry which has meant so much to the progress and prosperity of the West Coast and in this war to our entire nation, because men who established the industry here were willing to risk in hope of gain.

In spite of wars, depressions and disasters, the average American of today is better fed, better housed and better clothed than the people of any nation ever were in all the world's history. This condition is because Americans have been free to dream and study and think and plan—and have been able to make their dreams and plans come true. Many a business or political leader in the past and in the present has come from the other side of the tracks. Many of this nation's most brilliant men came up the hard way, sweated out their own educations and were glad of the chance. That accent on individualism, the opportunity of an American to rise as far, economically and socially, as his desires and his talents permit, has made this country rich, strong and powerful. If we substitute for this after the war any form of regimented economy, no matter how attractive or seductive the totalitarian blueprint may appear, these United States will cease to be the land of opportunity.

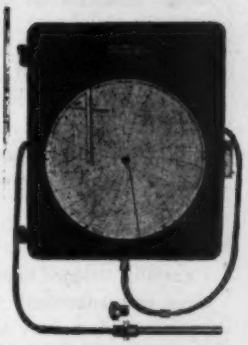
I do not suppose the "dry hole" has a friend in the world. Certainly it is no friend of mine, but I must admit that it tells us where not to drill again and yields geological information as well. However, there is no more fitting symbol of the kind of a United States we must preserve against all hazards than the dry hole. Because men in the United States have been willing to venture their savings in drilling a possibly dry hole, the great American oil industry has been established and has flourished for the benefit of all our people. Remove the hope of a compensating reward for the risk taken and no more oil wells will be drilled by individuals. If the world is to have oil, that principle must be kept constantly in mind and in practice.

May I repeat to you here in California something I said to a group of several hundred oil men in Dallas about one month ago, namely, that no one need fear for the future of the petroleum industry so long as there are wise and able men to lead the way and the leadership is not hogtied by needless political interferences. Our survival as a free industry depends upon our ability to provide the right sort of leadership and upon exercise by government of re-



We Cannot All Be Heroes and Win Fame

but it takes a steady worker like RUBY, who dreams of gallant ladies, as she graduates those fine lines on a waxed tube, so it will be accurate when used to test manufacturing processes of war materials.



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straint from needlessly regulating our industry in time of peace.

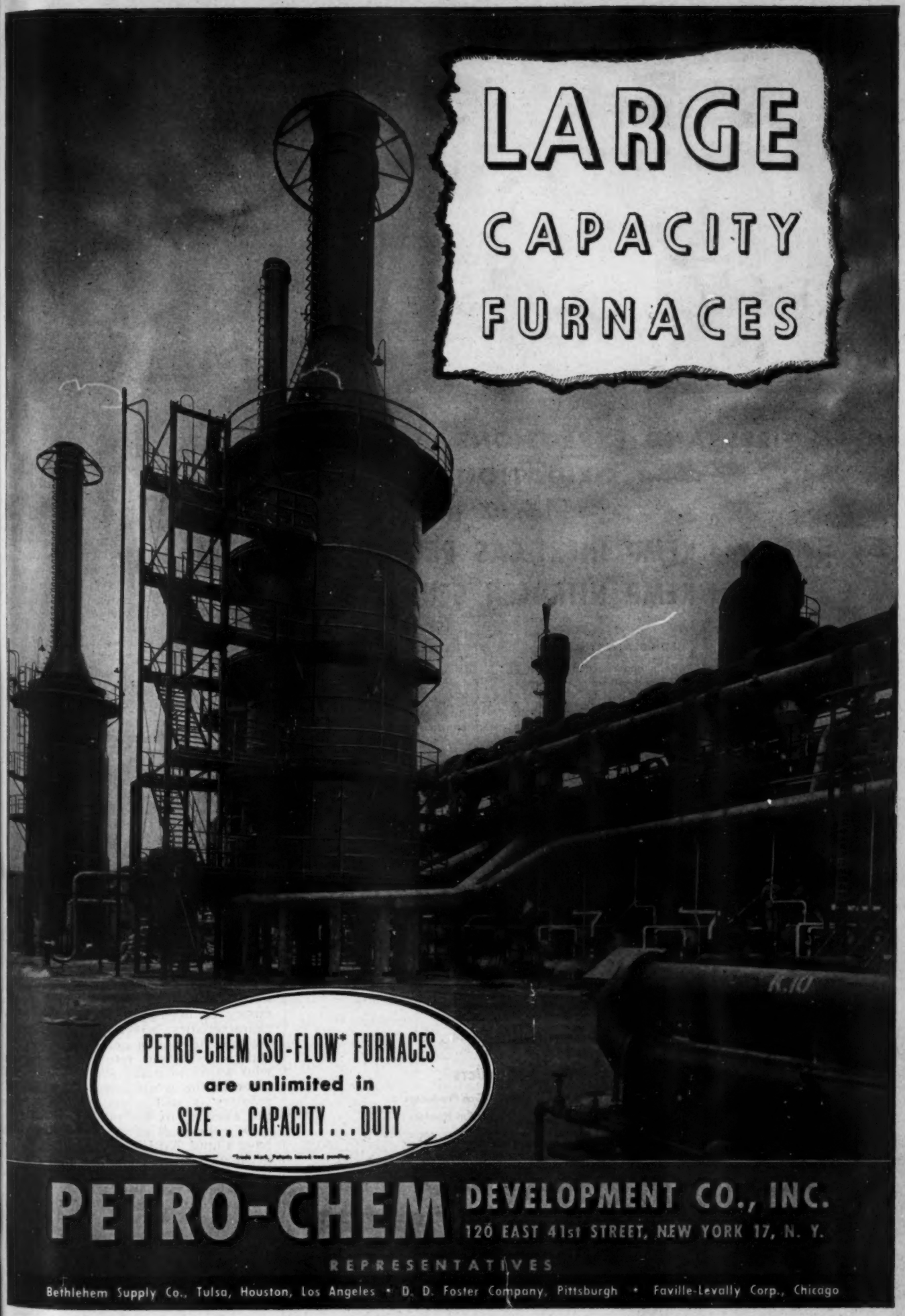
It is true that California has been blessed with great and rich oil fields. But California also has been blessed with men of courage and vision and daring, men who were willing to risk their capital to produce new wealth, new industries, new opportunities for thousands of their fellows. Freedom of opportunity and the courage to grasp that opportunity are as much responsible for California oil leadership as the fact that rich oil deposits exist in the state.

Government-Industry Cooperation

Due credit should be given by all to the appropriate government agency for the role it has played in making it possible for our industry to perform so successfully in this war activity. As chairman of the Petroleum Industry War Council I cannot address such a representative group of oil men as are here assembled without paying a deserved tribute to our astute Petroleum Administrator for War, Harold L. Ickes, the able, skillful, sagacious, and diligent Deputy Petroleum Administrator, Ralph K. Davies, who is a Californian, and the busy, intelligent, and competent staff of the Petroleum Administration for War. Operating the government agency which was authorized and directed to coordinate the industry's wartime activities, Secretary Ickes and Mr. Davies had the political courage to staff it with practical oil men and the foresight to admit the industry into full partnership, thus obtaining complete industry cooperation in solving the many problems that have arisen. it is a unique arrangement, the only one of its kind in Washington, I believe that official Washington and the Congress, and at least some of the public, are aware of the effectiveness of this cooperative government-industry team. It has done the wartime job in effective fashion and without friendly, intelligent cooperation between government and industry the job could not have been done.

I have been told frequently by outsiders that it appeared to them that in the oil industry everyone seemed to misunderstand everyone else engaged in the business; we are too prone to burst into volcanic eruptions; that everyone seemed to be going about with a chip on his shoulder daring everyone else to knock it off; and that, no one ever finds anything good to say about his competitors. Recently I heard the observation that the oil industry reminded one of a steam laundry because of its predilection to wash its dirty linen in public. Maybe once upon a time there may have been more than a grain of truth in some of this. But it is not true now. The war has brought the men of the oil industry close together. In working together, as they have during the entire war period, they have worked agreeably and they know successfully. It has been and is my fervent prayer that the men and companies engaged in the business of producing, refining, transporting and supplying petroleum products will maintain unity of purpose and action and continue to support uninterruptedly and cooperatively our government partnership arrangement until both Germany and Japan are completely crushed and peace is restored.

At the Annual Meeting of the American Petroleum Institute in Chicago in 1943, the last we held, two broad policies were discussed. The first was our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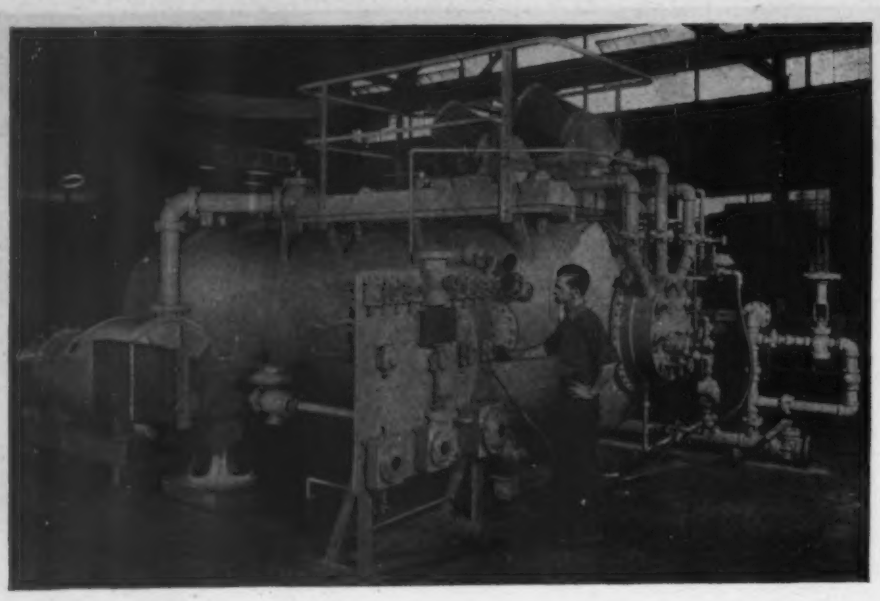

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industry's war job. This, we know, is being carried out with conspicuous success. The second was the need for telling the American people what we were doing and why we were doing it; not as a matter of self-seeking nor of boastfulness, but primarily as an educational program of patriotic import to all the people—a public service as straightforward as it should be sincere. In addressing that meeting, I said that while the Institute, as one of the numerous trade associations representative of and supported by the industry, proposed to do everything it could to help unfold the story of oil in war and peace before the American people, it is not the job of any one organization or any one central agency to tell the story. I said also, that the job must be done by each oil association, each oil company, each individual in its or his own name, and in its or his own way. May I say now with emphasis, that we do not want to make exaggerated gestures about ourselves. What we want to make is character for our industry.

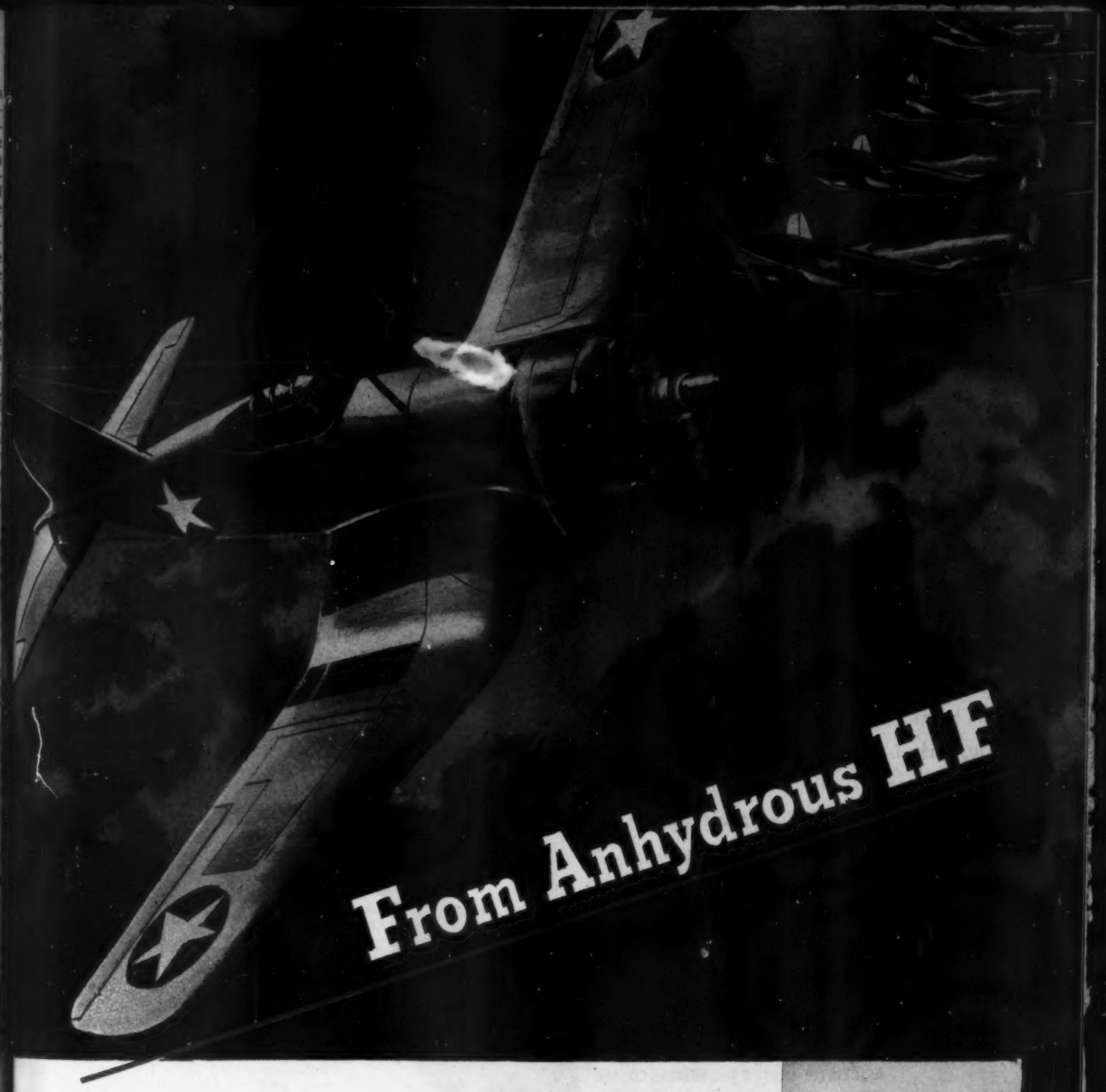
And may I say, too, that no group in the country has sought to reach that objective with greater skill and diligence than have the oil industry, the oil companies and the oil men of California. The advertising and informational programs carried on during the past year by the industry of the West Coast have been pertinent, interesting, factual and constructive, and I hope they will keep up the good work. I believe the public is eager to receive the real story of oil; oil; not only the story of oil's great part in the war but the continuing story of the progress of the industry in harnessing this great natural resource for human good and for human welfare.

Want Men Back

The problem uppermost in all our minds and hearts these days is that of getting our boys back home and returned to the pursuits of peace. I know that the management of every oil company, large and small, has given this question serious and careful consideration. It is a problem that each company must work out in its own way, but I am confident that it will be worked out for the greatest possible benefit to the returned soldier. Those oil company programs of which I have personal knowledge do precisely that.

We want our boys back and we want them back in our industry. We want them back sentimentally, but we also want them back selfishly. Brutal as war is, it makes for strong, disciplined, self-reliant men for whom the word "impossible" does not exist. The petroleum industry has been built by men with those characteristics, which leads us to look beyond the war in complete confidence and to assure our returning oil-veteran who wants to make for himself a real place in the world's work that the oil industry is still a good place for the full exercise of his talents.

Of course all of us must realize we have a long, hard row to hoe before that great day comes when all the boys return. Despite the continuing good news from Germany, Iwo Jima and other Pacific Island outposts which we have taken have demonstrated that the road to Tokyo is a rocky one. The Japs apparently intend to continue their bitter and savage warfare to the very end, unwilling or unable to drop their vain dreams of conquest and of empire. This means that our industry, in cooperation



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' ' '

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Cooperating with industry toward furnishing *"special"* chemicals in commercial quantities *is part of our service to American enterprise.* If you are using such chemicals, it will pay you to investigate General Chemical's service in furnishing your requirements!

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Associated forged steel flanges in carbon, alloy, carbon moly, chrome moly, stainless, or other specified alloys are widely known and used wherever flanges are required.

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with the Petroleum Administrator for War and all other agencies of government having authority over us, must continue to provide all the petroleum products necessary until the war has finally ended. Because of the distances involved and the fact that all materiel must be moved thousands of miles across the Pacific, the task is going to be defyingly difficult. The splendid record and outstanding accomplishments of the California oil industry thus far in the war must be continued. The same responsibility rests upon all other producing areas and all other producing and refining centers wherever located throughout the world. It is going to take a lot of doing. No one in government doubts our industry's willingness or ability to do it.

In the years to come it seems not unlikely that an enforced peace may prevail. At the San Francisco Conference scheduled for April, some sort of world organization of nations will be agreed upon. Besides the will to maintain peace, the responsible powers must also have the means. Those means obviously comprise a Navy, an Air Force and an Army that separately or together can and will promptly and effectively suppress any attempts to break the peace. Our taste of disarmament taught us that an unarmed policeman was not very effective. Maintaining the peace will be expensive in money and resources but it will not approach the cost or the waste of war.

In this war petroleum powers the attack. It can also preserve and power the peace. If the oil is available. I believe that our 1950 civilian and military consumption of petroleum will exceed that of this year. The oil will be available if everyone appreciates the importance of gasoline, fuel oil and other petroleum products enough to insist that the petroleum industry be given the green light to conduct its vast responsibilities.

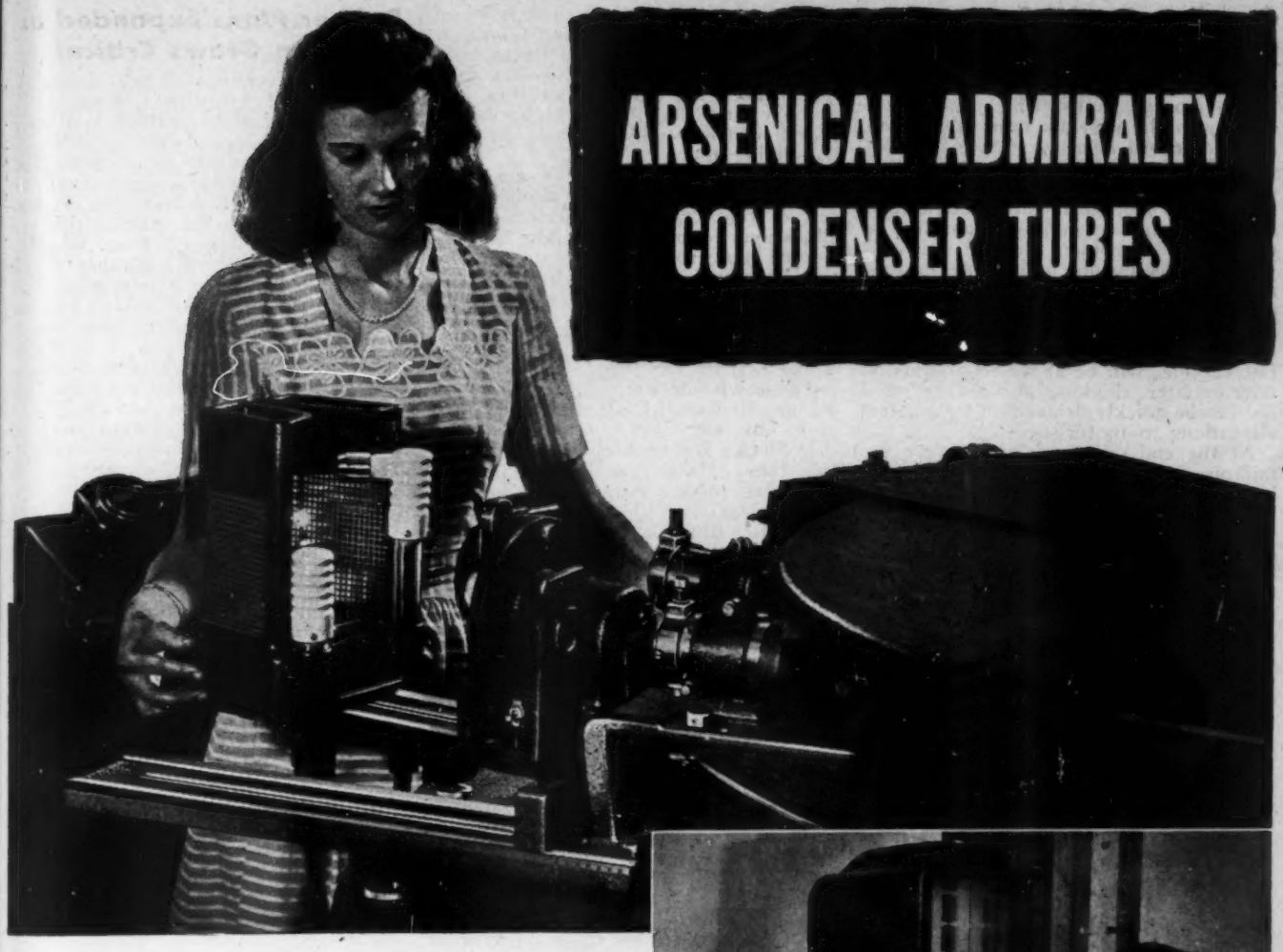
I am not apprehensive about the future of the oil business. I know that the magic towers and the indomitable men who use some of them to drill deeper and more distant wells to maintain the flow of crude oil to those other towers of magic wherein all manner of products are so cleverly made, will continue for time beyond ken to provide our people with the myriad forms of petroleum that have become so vital to war and so pertinent in peace!

All-for-War Plant Makes Million Barrels 100-Octane

Associated Refineries, Inc., Duncan, Oklahoma, recently manufactured its millionth barrel of 100-octane gasoline, in a plant that differs from other refineries turning out this product for the war in that it was built during the emergency from the ground up, and not as an addition to an existing plant. Designed by Universal Oil Products Company, the plant combines catalytic cracking, gas concentration, alkylation and isomerization, and draws its raw material from eight refineries in South Oklahoma and North Texas. It went on stream early in 1944. Plans are being made to increase capacity.

Officers of Associated Refineries, Inc., include M. Lloyd Freese, president; L. B. Simmons, chairman of the board; B. I. Lubell, R. B. Anderson and R. C. Stanford, vice presidents, and Dr. H. B. Alspaugh, secretary-treasurer.

ARSENICAL ADMIRALTY CONDENSER TUBES



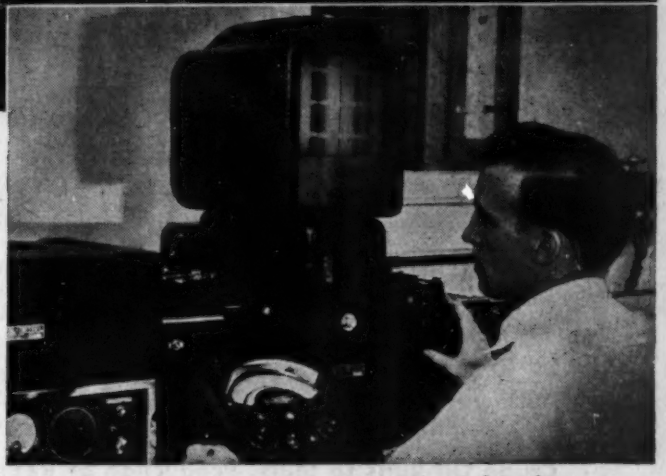
An improved alloy with high resistance to dezincification

NOT a "cure-all," but a tube alloy to consider if you are troubled with dezincification. The American Brass Company has been manufacturing Arsenical Admiralty Tubes on a commercial basis since 1934, and now furnishes this alloy as standard for Admiralty Tubes*.

This alloy was the result of studies of the effect of small quantities of arsenic introduced in brass alloys as an inhibitor of dezincification.

The consistently satisfactory performance of Arsenical Admiralty Tubes, over the past 11 years in many types of service has substantiated the results of laboratory tests.

While Anaconda Arsenical Admiralty Condenser Tubes have been quite generally used, they are especially well-adapted to those installations in which the older alloys showed definite tendencies to dezincify.



(At top) grating type spectrograph used to determine Arsenic content in Arsenical Admiralty Condenser Tubes. (Above) Densitometer-Comparator used to read spectra taken on the spectrograph.

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It is a function of the engineers of our Technical Department to assist Condenser Tube users in the selection of the most economical tube alloy for any given set of operating conditions. Feel free to call on us. Publication B-2, sixth edition, giving detailed information on Condenser Tube and Tube Sheet Alloys mailed on request.

**Admiralty Alloy Tubes without arsenic will be furnished only when so specified.*

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Gasoline Stocks Begin Crowding Storage Space

The quantity of gasoline in United States storage tanks, which has risen sharply in the past six months to near all-time record levels despite expansion of military activities, is beginning to cause worry. There results an acute shortage of storage facilities. Some fear this means an over-supply of gasoline is to become a problem for the industry soon. Others do not look upon the immediate situation as holding disturbing possibilities, but do think the end of World War II will complicate the problem. Still others do not agree that gasoline supplies will be above requirements now or later, thinking any excess supply can be quickly drained off by greater allocations to motorists.

At the end of March there were 99 millions barrels of gasoline in storage in the United States, a near all-time high which compares with the peak of 109 million barrels in mid-March, 1942, and with a wartime low of 68 million barrels in October, 1943. Gasoline stocks have risen 13½ million barrels above a year ago, and 20 million barrels since last October 1. There has been an 11½ million barrel increase since last June, or since military use became exceptionally heavy. Allied armies did not invade Normandy until June and the Philippines and other Pacific islands have been invaded during this period.

Those who fear there will soon be a serious oversupply of gasoline say that any additional growth in stocks will cause the current storage facility shortage really to become acute. Refiners, then, would have to find some way to dispose of more gasoline, or curtail plant output. This group expects stocks to continue to increase as long as record output of motor fuel is maintained, for these reasons:

1. The sharp growth that has occurred in the past year despite peak military use;

2. Military consumption after the war with Germany ends probably will be no larger, if as great, as in the past year;

3. Large additional quantities are likely to go to storage between defeat of Germany and all-out warfare against Japan;

4. The situation cannot be considered as seasonal, although gasoline stocks customarily reach their highest levels of the year the end of March, because there will be less seasonal fluctuations than usual. Curtailment of civilian driving reduces the effect of weather, and military use has been high during March which usually is a low gasoline-consuming month;

5. Civilian gasoline stocks are quite low, constituting but 53½ million barrels of the total, and therefore larger allocations to motorists might be considered dangerous not only to car and tire conservation but also from a gasoline supply viewpoint unless some military fuel is released.

Some See No Trouble

Those who do not think the immediate gasoline stocks situation disturbing point out that:

1. Stocks are no higher now than at this time of the year in prewar 1941, and that total consumption (military and civilian) is higher;

2. The situation is seasonal, and stocks will be reduced during the summer. (Even in all three of the war years, gasoline stocks have declined in the summer and increased in the winter);

3. Military authorities say there will be no decrease in gasoline consumption by armed forces after Germany surrenders;

4. Any surplus can be eliminated by larger allocations to civilian motorists. If the drivers of the 20-odd million cars are given one more gallon per week, gasoline consumption would be increased by 75,000 barrels daily, almost equal the average increase of the past six months. Such an increase, they say, would not damage tire or car conservation efforts.

All those who look upon the current situation as discouraging, plus many of those who are not disturbed by present conditions, view with concern the prospects following cessation of all hostilities. They are fearful because:

1. There will be a sharp reduction in gasoline consumption when military use declines and before civilian automobiles get back to normal driving habits;

2. The military probably will have large quantities of gasoline in storage at the end of hostilities, and no matter how it is disposed of, it will absorb a part of the existing demand.

Rubber Plans Expanded as Situation Grows Critical

Further expansion of copolymer and raw material facilities costing in the neighborhood of $22,000,000 and bringing the investment in government-owned rubber plants to close to $750,000,000 will be necessary to meet the anticipated increased demand for synthetic rubber during the last half of this year and in 1946, it was disclosed in a 1944 year-end report of the Rubber Bureau released by the War Production Board.

Production of buna-S rubber last year totaled 668,834 long tons, and 1945 requirements are now placed at 881,000 tons and may be increased by reason of the expanded heavy tire program; 1946 requirements are now set at 1,054,000 tons, which is 22.5 percent over the present demonstrated capacity and 49.5 percent over the rated capacity of the plants.

"It is indeed fortunate that the synthetic rubber plants have demonstrated a flexibility in production and an ability to produce substantially over their rated capacity, so that with comparatively small additions an output up to nearly 50 percent over their rated capacity can be counted on for 1946 if needed," the report commented.

The most serious problems which the industry will face in its efforts to achieve 1945 and 1946 production goals are manpower, rayon and cotton tire cord, carbon black and beadwire.

J. F. Clark, director of the bureau, said increased production of tires and tubes represents the No. 1 war production problem, and the translation of the increased tire and tube program into crude and synthetic rubbers has again made crude rubber the most critical of all strategic materials.

The production schedules adopted last November—which are expected to be increased substantially—required 144,000 tons of crude rubber in 1945, calling for withdrawals of about 35,000 tons from the government's stockpile, as estimated imports will be less than consumption, driving that inventory down to 61,000 tons by the end of the year. The stockpile on January 1, last, was 96,000 tons, much below a safe minimum for the nation.

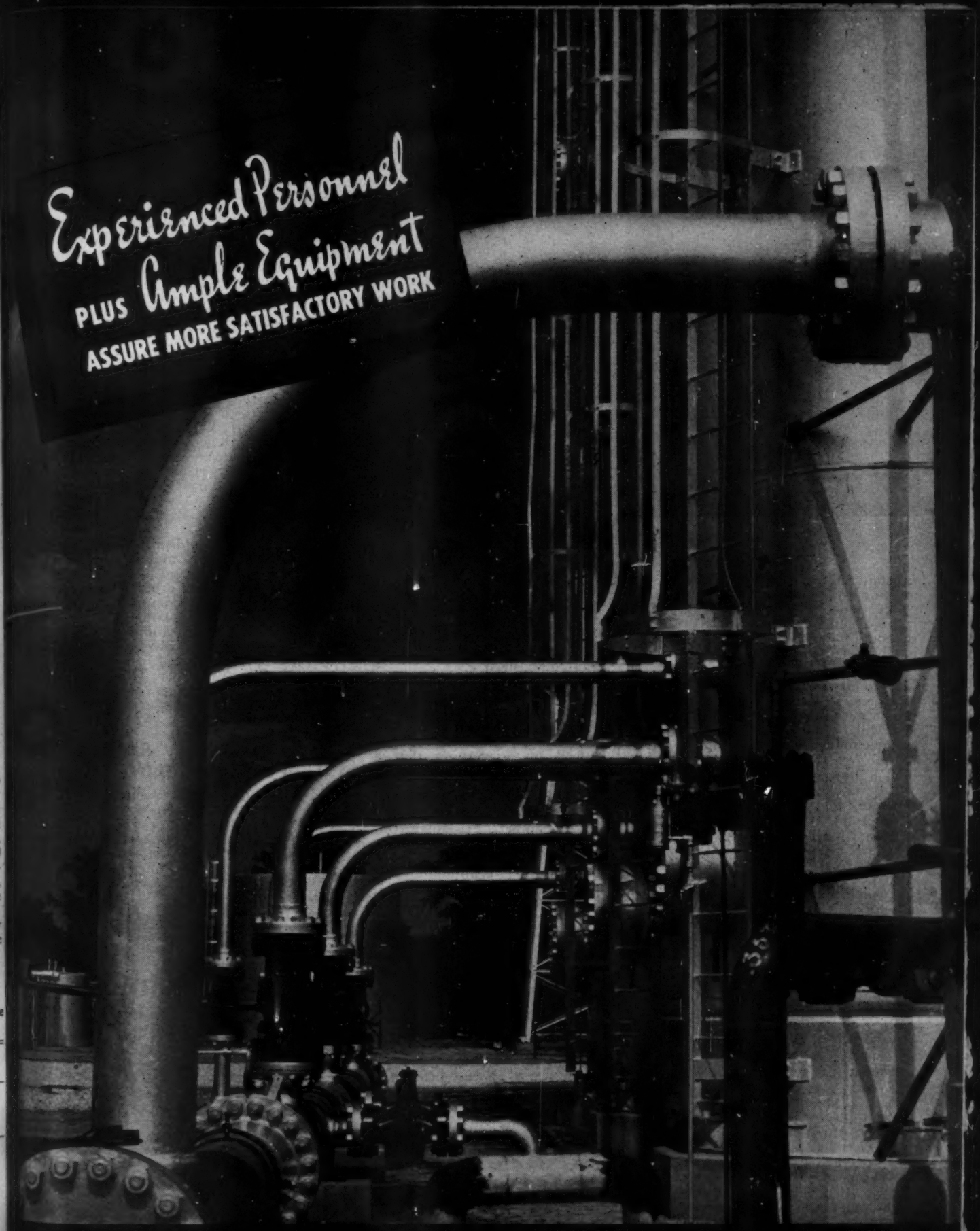
Production schedule of 4,875,951 heavy duty tires for the first quarter will be

Crude Oil Runs to Stills, Production of Refined Products, and Stocks for the Four-Week Period Ending March 24, 1945

(Figures, in thousands of barrels of 42 U. S. gallons each, based on reports of American Petroleum Institute. Production and stocks include reported totals plus estimated amounts to make these figures on a Bureau of Mines basis)

DISTRICT	Capacity Percent Reporting	Crude Runs to Stills: Daily Average	Crude Runs to Stills: Percent Operating	Production: Gasoline*	Production: Kerosine	Production: Gasoil and Dist. Fuel Oil	Production: Residual Fuel Oil	Stocks at Refineries, Terminals and in Pipe Lines: Finish and Unfinished Gasoline	Stocks at Refineries, Terminals and in Pipe Lines: Kerosine	Stocks at Refineries, Terminals and in Pipe Lines: Gasoil and Dist. Fuel Oil	Stocks at Refineries, Terminals and in Pipe Lines: Residual Fuel Oil	Crude Oil: Daily Average Production	Crude Oil: Stocks†
East Coast	99.5	710	90.7	7,616	913	3,777	6,183	13,838	1,948	5,285	5,618	.....	.....
Appalachian District 1	76.8	99	68.2	1,186	237	322	441	2,489	240	373	248	.....	.....
Appalachian District 2	81.2	60	119.5	745	49	223	386	1,482	33	120	163	.....	.....
Illinois, Indiana, Kentucky	87.2	781	91.1	11,590	1,031	2,725	4,395	24,239	1,372	3,351	1,846	.....	.....
Oklahoma, Kansas, Missouri	78.3	385	82.1	5,730	685	1,616	1,952	9,872	453	1,691	1,188	.....	.....
Inland Texas	59.8	231	70.3	3,756	351	550	1,370	3,085	140	335	599	.....	.....
Texas Gulf Coast	89.3	1,162	93.5	13,567	1,395	5,853	7,486	16,426	1,048	5,038	6,315	.....	.....
Louisiana Gulf Coast	96.8	265	101.8	2,967	976	1,320	1,178	5,040	918	1,903	1,502	.....	.....
North Louisiana, Arkansas	55.9	72	57.3	848	200	210	469	3,000	124	707	284	.....	.....
Rocky Mountain District 1	17.1	11	84.6	135	16	31	89	85	15	15	30	.....	.....
Rocky Mountain District 2	72.1	115	72.7	1,627	102	287	798	2,508	120	349	590	.....	.....
California	85.5	861	87.1	8,886	249	2,074	11,398	16,948	448	7,615	24,944	.....	.....
Total U. S. March 24, 1945	85.5	4,761	87.6	58,649	6,604	18,888	36,445	99,012	6,859	26,782	43,327	4,772	219,486‡
Total U. S. February 24, 1945	87.5	4,755	96.8	.....	.....	.....	.....	95,972	7,514	28,753	46,723	4,752	219,351
Total U. S. March 25, 1944	.....	.....	.....	.....	.....	.....	.....	85,583	6,476	30,925	52,475	4,385	236,285

* Includes natural gasoline blended at refineries. † Bureau of Mines. ‡ March 17, 1945.



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substantially achieved, but chances for meeting the increased second-quarter production of 5,726,671, as programmed last November, appear unlikely, and the schedule for truck and bus tires already has been cut to 5,085,604.

A gradual improvement in April and May is forecast, however, as a result of intensive measures taken to increase the output of carbon black and the situation will be more stabilized by the end of the coming quarter. When all projects in the expansion program are completed, however, maximum production will be in excess of 28,500,000 truck and bus tires per year.

The total demand for rubber this year will be 1,133,000 tons, of which 976,000 tons will be synthetic and 157,000 tons natural; total supply is estimated at 1,143,000 tons, of which 1,020,000 tons will be synthetic and 123,000 tons natural. Requirements last year were 854,000 tons and supply totaled 907,000 tons, 798,000 of it synthetic. With the supply of synthetic rubber running consistently in excess of requirements, a stockpile is being built up. This should total 189,000 tons by January 1.

WPB Chairman Krug announced that John L. Collyer, president of the B. F. Goodrich Company, has been appointed special director of rubber programs for a three-month period.

Taking over his new post, Collyer issued a statement warning that the present necessity for tire and other products production will continue until both Germany and Japan are defeated and civilian requirements met.

"The position today, in terms of military and civilian shortages, is more severe than at any time since Japanese conquest of the world's principal natural rubber sources forced the United States to build a whole new industry—synthetic rubber—to provide the main raw material for tires and other war necessities," he said. "Government and industry already have performed a near miracle in creating this new industry.

"Although consumption of synthetic, natural and reclaimed rubber is at a rate greater than in any prewar year, we still face dangerous shortages of tires and other vital rubber products.

"In coping with the complex rubber problem the United States has been attacking a moving target. War demands have gone up. A new government program to provide increased military tire manufacturing facilities is scheduled to come into production during the latter months of this year, augmenting the expansion of existing plants and the creation of new manufacturing units undertaken in 1943 and 1944. Until these new plants are complete and in full operation, the nation's military and essential civilian tire stocks will continue to be critically short."

Increased Synthetic Rubber Output Planned

Rubber Reserve Corporation has called for a 31-percent increase in production of synthetic rubber over the 763,255 tons manufactured in 1944, and set the 1946 goal at 1,200,000 tons.

To reach these objectives, the agency said, it will be necessary to increase production to 130 percent of rated capacity by the middle of this year, and to meet the 1946 goal production must be jumped to 145 percent of present capacity. These operations will be possible, however, it was said, because research, scientific development and operating experience have led to many refinements in production techniques.

Adequate supplies of petroleum, alcohol and chemicals must be made available if the program is carried out, it was emphasized.

Announcement was made by Transportation Director J. M. Johnson of a 50 percent cut in the number of heavy-duty tires allocated to commercial vehicles for the second quarter, accompanied by a warning that a further reduction may be necessitated if shortages of carbon black and other tire components are not remedied.

In another action, RFC increased to 32 the number of tire-plant construction and expansion projects which it is financing in an effort to increase the output of tires in a minimum of time.

Carbon Black Increased Output Program Approved

A 14-point program to meet the current grave need for increased supplies of carbon black, which will be international in scope, was laid down March 29 by the Inter-Agency Carbon Black Committee appointed March 10 by Mobilization Director James F. Byrnes to deal with the major problem barring the scheduled production of rubber and rubber products.

When the program is fully underway an additional production of 188,100,000 pounds of carbon black a year will be added to present facilities.

PAW, beginning immediately, will make available 115,000 gallons of propane gas per day, which will permit an increased production of a million pounds of carbon black per day. As soon as heating demands recede, probably within a month, it will make available an additional 150,000 gallons of propane gas daily, and as soon as equipment to process it is installed, requiring six weeks to two months, will provide 10,000 barrels of naphtha and 2000 barrels of gasoline residue daily, adding approximately 1½ million pounds per month of carbon black.

In addition, the Texas Railroad Commission is assisting by obtaining additional sources of gasoline for several carbon black plants in the state, which it is estimated will permit the manufacture of another 1½ million pounds monthly.

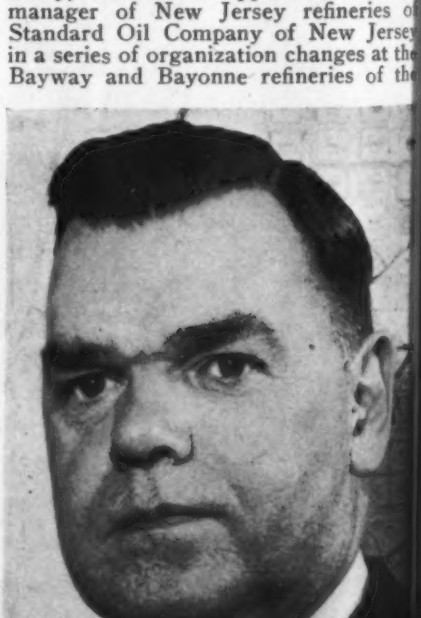
The War Department has been requested to take steps to obtain production of carbon black from existing facilities in France; production of carbon black in California, the Mid-Continent areas and in Canada where sweet gas may be used is being pushed, and in Louisiana other steps are being taken to permit the use of sweet gas.

The various federal agencies, particularly PAW, are taking steps to make enriched gas available to the industry wherever possible, thus providing for increased production from existing facilities of as much as 40 percent in some plants, the committee reported.

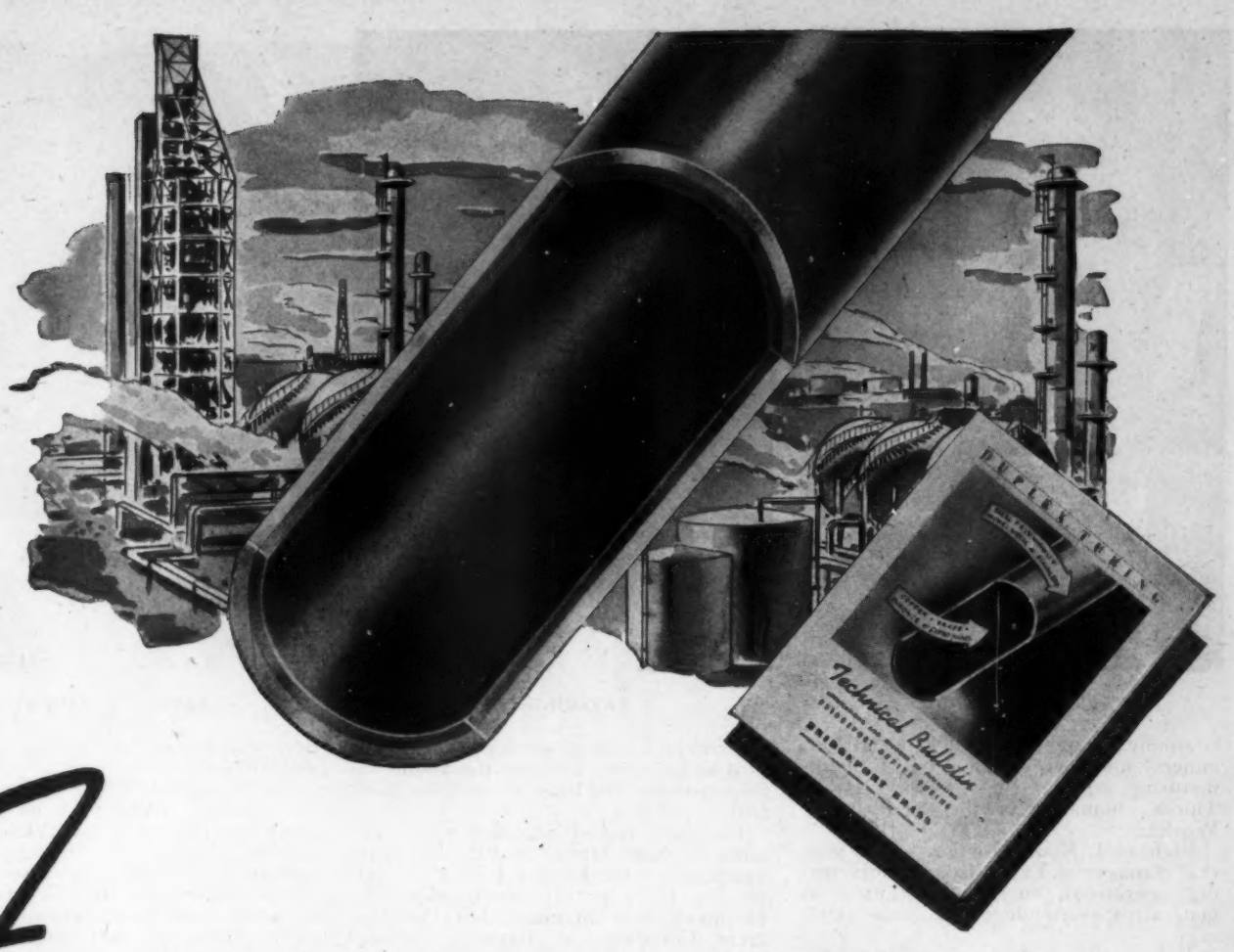
Included in the construction program, for which WPB will provide the necessary priorities and in the financing of which Defense Plant Corporation will participate, are supplementary facilities at Cities Service Oil Company plants in Ector County, Texas, to cost $224,000, and North Cowden, to cost $150,000; additions to Phillips Petroleum Company plants at Borger, Texas, to cost $379,810; Goldsmith, Texas, to cost $53,000, and Eunice, New Mexico, to cost $142,826, and new and added facilities for Cabot Carbon Company, Columbian Carbon Company, J. M. Huber, Inc., Jefferson Lake Sulfur Company, Charles Eneu Johnson & Company, The Roxboro Steel Company, United Carbon Company, and United Carbon Judkins Company. The program, representing 40 percent of the expansions regarded as necessary, will cost, all told, $11,371,970.

New Jersey Refinery Personnel Shifted

Donald L. Ferguson, general superintendent of the Bayway, New Jersey refinery, has been appointed assistant manager of New Jersey refineries of Standard Oil Company of New Jersey in a series of organization changes at the Bayway and Bayonne refineries of the



DONALD L. FERGUSON



Fighting a Two-Front Corrosion War . . .

WITH BRIDGEPORT'S DUPLEX TUBING

Engineers know that a single metal or alloy frequently fails when the inside and outside walls of tubing are attacked simultaneously by two different types of corrosive elements. Duplex Tubing divides and conquers this two-front corrosion war by treating such cases as two separate corrosion problems.

Two tubes, each capable of resisting a specific type of corrosive attack, are combined to form a single Duplex Tube, with inner and outer walls of different materials, and able to withstand double corrosion which would destroy either metal or alloy alone.

For example, Duplex Tubing is being used in refrigeration systems with ammonia gas on one side of the tubing and cooling water on the other; in chemical processing condensers and coolers with various liquids or gases on one side of the tubing and fresh or salt water on the other. Bridgeport's Admiralty, Cuzinal, Red Brass, Copper, Duronze IV and Cupro Nickel are combined with aluminum, steel or monel in such applications.

Contact your nearest Bridgeport office for assistance in solving severe double corrosion problems, and in the meantime write for a copy of Bridgeport's technical bulletin describing applications and methods of installing Duplex Tubing.

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company announced by J. R. Carringer, general manager of East Coast manufacturing operations, and William Thiedo, manager of the New Jersey Works.

Richard J. Kaul, assistant to the general manager of East Coast manufacturing operations, succeeds Ferguson as general superintendent of Bayway refinery.

J. Raymond Eiffe has been appointed assistant general superintendent and process superintendent at Bayway, and Bryant F. Kenney has been transferred to the New York offices of the company as assistant to the general manager of East Coast operations.

Willard F. Wadt has been appointed acting process assistant to the manager of New Jersey Works; Charles E. Borgstrand has been made acting process superintendent at Bayonne; and Francis J. Powers, assistant process superintendent at Bayonne, assumes the additional responsibility as head of process control.

Ferguson joined Standard Oil Company of New Jersey in 1920 following graduation from Purdue University. After six years in the development department, now Standard Oil Development Company, at Bayway, he was made assistant superintendent of the Everett, Massachusetts refinery of Colonial Beacon Oil Company, subsequently becoming general superintendent, and later manager and a director of Colonial Beacon. He spent more than three years in France as manager of the Port Jerome refinery of Standard-Francaise des Petroles, returning to the Bayway refinery as assistant general superintendent in 1938. He was made general superintendent at Bayway in 1940.

Kaul joined the company as a student engineer after graduation from Stevens Institute of Technology in 1923. He served nine years as superintendent of the chemical products plant, and in 1943 was made assistant to the New Jersey Works manager. Shortly after, he became assistant to the general manager of East Coast manufacturing operations, and last year assumed the additional duties of secretary to the manufacturing committee.

DR. H. D. WILDE

Dr. H. D. Wilde Heads All Humble Research

Dr. H. D. Wilde, manager of the technical and research division of Humble Oil & Refining Company's refining department since 1933, has been appointed to the newly created post of manager of research and development for the company.

In the new assignment Dr. Wilde has general supervision and coordination of the work of three distinct groups serving the principal departments of the company—the technical and research division of the Refining Department which carries on technical services, control testing, research and development work at the refineries; the geophysics research division of the geologic, land and lease department, and the production research division of the production department.

Dr. Wilde, whose employment with the company dates back to July, 1927, from the University of Texas, received his bachelor's degree in chemical engineering in 1923 and the master's degree the following year. He did part-time instructing work in the chemistry department during his last three years. For three years following his graduation from the University of Texas he attended Massachusetts Institute of Technology, working toward his Doctor's degree and doing part-time work on the staff of the research laboratory in applied chemistry.

Late in 1926 he came to Baytown refinery to gather data for his doctor's thesis, which involved a study of plate efficiency in commercial petroleum fractionating towers. He completed this thesis after being employed in the technical and research division at Baytown in July, 1927, and in 1929 was granted his doctor's degree in chemical engineering from M.I.T.

The same year he was called into Houston to organize and become head of a new group to carry on the company's production research. He remained in this capacity until 1933, when he became head of the refining department's technical and research division.

Dr. Wilde has been active in scientific societies, has addressed many of these organizations and has written numerous technical papers. He is a member of the American Chemical Society, American Institute of Mining and Metallurgical Engineers, American Institute of Chemical Engineers, American Petroleum Institute, and a member of the Technical Advisory Committee to the Petroleum Industry War Council and the Aviation Gasoline Advisory Committee.

Since the outbreak of war he has taken an active part in the work of District 3 Petroleum Industry Committees on studies dealing with increasing supplies of 100-octane gasoline, production of butadiene for synthetic rubber, and the use of minimum quantities of crude oil for the production of maximum quantities of petroleum products.

To the final Victory, Natural Gasoline will be as important as it has been in helping build the American-Way of life through the growth of gasoline powered transportation . . . with the dawn of peace STA-VOL-ENE the "Natural" known throughout the world will contribute much to the many new developments that are forecast for tomorrow.

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Oil Company Researchers Help Set Japan Afire

Incendiary raids on Japanese industrial centers scheduled to receive B-29 Superfortress attention were made possible by petroleum industry know-how, it was disclosed by Standard Oil Company (New Jersey), whose personnel was loaned to the Army Chemical Warfare service to aid in development of the unquenchable bomb which burned out large sections of Japan's cities.

The "M-69" oil incendiary bomb, demonstrated publicly last June at the company's proving grounds at Bayway, contains jellied gasoline which is forcibly scattered upon impact in gobs of sticky flaming material which clings to the sides of buildings or spreads inside them if the roof is pierced. The bomb can be dropped in aimable clusters.

The M-69 looks like a piece of hexagonal pipe, it is cut off square at the ends and has no fins. It receives its stability from cloth streamers which come out when the bomb falls free. The streamers slow the fall of the bomb to a speed which gives it adequate power to pierce a roof without damaging its internal mechanism. Dropped in clusters, the bombs scatter as they fall earthward.

The bomb is equipped with an inertia fuse and a powder train that ignites an explosive mixture which hurls a cheesecloth sack of 2½ pounds of jellied gasoline out of the tail of the metal container with enough force to smash the bag and scatter flaming "goo" against a building as much as 100 feet away from where it falls.

Questionnaire Delayed as Refiners Discuss Costs

Representative refiners met with OPA officials March 15 to discuss the proposed investigation of refining costs suggested by the House Small Business Committee, which is to supplement study on the cost of producing crude oil.

Unlike the meeting some weeks ago at which a procedure for the crude oil cost survey was worked out, OPA went into the meeting with no ideas what the refiners would want and left it up to the industry committee to develop not only the manner in which the study would be made but also the ground to be covered.

Meanwhile, it became apparent that more time will elapse before a questionnaire is ready for distribution to the selected sample group whose costs will form the basis of any OPA determination of the adequacy of present crude oil prices.

The form has been approved by the various individuals and organizations but the overloaded Government Printing office will delay its production.

Anchor Buys Cimarron Gasoline Corporation

Anchor Petroleum Company, Tulsa, has purchased the stock of Cimarron Gasoline Corporation, also of Tulsa, which operates natural-gasoline plants located at Coyle and Guthrie, Oklahoma. The combined capacity for the production of natural gasoline and liquefied petroleum gas from the two plants approximate 50,000 gallons per day.

Neches Butane Company Makes Personnel Changes

Neches Butane Products Company, Port Neches, Texas, recently made the following changes in its executive personnel:

H. P. Arbuckle, formerly secretary-treasurer, has been promoted to vice president and secretary. He is a 25-year man with Gulf Oil Corporation, from which he is on leave of absence and assigned to his present connection.

I. H. Fooshee has been elected vice president in charge of manufacturing. For the past two years he has been with Rubber Reserve Company. He also is on leave from Gulf Oil Corporation to assist in the synthetic rubber program.

F. W. Cooper has been promoted from assistant treasurer to treasurer. He is on leave of absence from The Texas Company to assist with the rubber program.

Chemists Organize Chapter In San Francisco Area

Northern California Chapter of the American Institute of Chemical Engineers, inaugurated in the San Francisco Bay area late last year, has had an average attendance of 90 at 4 regular meetings. About 25 companies are represented in the organization, and 12 companies have 4 or more representatives.

Officers of the chapter include C. R. Nelson, Shell Development Company, chairman; O. M. Chinnock, Hercules Powder Company, vice chairman, and Matt Souders, Jr., Shell Development Company, secretary-treasurer. The executive committee includes A. George Stern, Westvaco Chlorine Products Company; G. C. Gester, California Research Corporation; G. H. Hemmen, Union Oil Company of California, and R. S. Trouton, Standard Oil Company of California.

PAW Will Spend Less Money During Next Fiscal Year

Petroleum Administration for War will require approximately a million dollars less for its operations for the year starting July 1. This was revealed when President Roosevelt included $4,245,000 for the oil agency in his request for $1,120,453,000 for operation of civilian war agencies.

Most of the agencies will operate on less during the year, but cuts are not in so great proportion as to indicate material relaxation of controls, and the total drop of $46,000,000 in the budget request was less than half the amount the President had indicated in January it would be reduced. In contrast with most reductions, Office of Price Administration gets an increase of $15,000,000 to $178,000,000 for "an intensified enforcement drive."

War Production Board's $48,042,000 is for "expected continuation of a tight civilian supply situation," and to provide for meeting constant changes anticipated in the military program. Selective Service was given funds on a basis of con-

H. P. ARBUCKLE

I. H. FOOSHEE

F. W. COOPER

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increases resistance to dezincification without increasing the initial cost of the tubes

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templated induction of 93,000 men monthly after July 1, before which 135,000 monthly will be needed. Foreign Economic Administration was increased $1,000,000 to $19,002,800, "to provide for enlarged staffs to prepare plans for economic control of enemy countries and review of supply programs in liberated areas."

Argyle and Brown Resign From PAW Refining Posts

William Argyle, associate director of refining, and Henry M. Brown, district 3 director of natural gas and natural gasoline, resigned from the staff of PAW March 1. Brown, who is president of Midland Gasoline Company, Houston, was guest at a banquet April 12, when more than 100 of his business associates gathered in recognition of his services within the district.

Argyle, who joined PAW in September, 1943, has resumed his former duties as assistant manager of refining for Sinclair Refining Company, New York.

Workers Recruited for Refinery in Saudi-Arabia

Twelve hundred Italians from Eritrea have been recruited for construction work on the Ras Tanura refinery of Arabian American Oil Company in Saudi-Arabia.

In an effort to complete the refinery before schedule, the company has hired also all the Arabs, Iraqi, Indians and others who would work on the project.

Families of the Italian workers were returned to their homeland in 1941 and 1942 but the men were stranded in Eritrea, where they had been employed on an American construction project after the British took over the Italian colony. They signed up for the refinery job to accumulate enough money to return to Italy.

Completion date of the project and its refining capacity is not disclosed for military reasons.

Preferred Status Asked For Smaller Refineries

Legislation directing the Secretary of the Interior to grant preferences in sale of royalty oil from the public domain to refiners who do not have their own source of crude oil supply has been introduced by Senator Joseph C. O'Mahoney of Wyoming.

O'Mahoney pointed out that while the present law gives the Secretary authority to collect government royalty in either cash or oil, it has been the practice to sell it to the highest bidder, which ordinarily means that small refiners who are not also the owners of producing lands find it difficult to get oil in competition with large refineries.

"The whole philosophy of the leasing act was to encourage small enterprise," he explained, "and the new bill would have the effect of giving the small refineries an opportunity to obtain their crude oil from the government royalty oil. The bill would authorize sale to such refineries at private sale at not less than the market price."

The senator asserted that highly satisfactory results have come from the legislation he introduced in 1942 to provide a flat royalty of 12½ percent for 10 years as a reward for the search for new sources of oil having been made on the public lands.

Biggest Demand Yet Seen In PAW April Schedule

A new high in crude-oil production has been called for by PAW in certifying need during April for 4,827,800 barrels daily, an increase of 34,450 barrels over March. Natural gasoline and condensate output is estimated at 329,160 barrels daily, an increase from 235,410 barrels in March.

Texas was asked by PAW for 2,330,000 barrels daily, involving a boost of 10,000 barrels of oil and 4000 of other liquids, to provide additional oil to be moved from West Texas to California. Texas conservation officials set their rates to provide 2,332,592 barrels daily, including 162,314 barrels of 'other liquids." Oklahoma was asked for 365,700 barrels of oil, up 2700 barrels, and California was unchanged at 818,000 barrels, a quota which it has been having difficulty meeting. California natural-gasoline-condensate potential was dropped 250 barrels to 58,560 barrels daily.

Asphalt Institute Holds Annual Meeting

The Asphalt Institute at its recent annual meeting in New York re-elected Herbert Spencer its president, Bernard E. Gray, general manager-chief engineer; George R. Christie, secretary-treasurer, and John N. Smith, assistant treasurer. H. B. Pullar, Berry Asphalt Company, was named chairman of the executive committee, this committee including Ole Berg, Jr., Union Oil Company of California; C. E. Cox, The Carter Oil Company; F. R. Field, Standard Oil Company of New Jersey; A. M. Maxwell, The Standard Oil Company (Ohio); F. V. Widger, Witco Chemical Company, and J. S. Williams, Rock Island Refining Company. Field, Maxwell, Cox, Williams and Berg are regional vice presidents.

Seek Petroleum Reserve Corporation Dissolution

Liquidation of Petroleum Reserve Corporation has been demanded by Senator E. H. Moore of Oklahoma in a joint resolution which he used as a springboard for an attack on government corporations which have been operating practically independent of congressional and budget control.

Moore told the Senate that PRC has had only one project—the attempt to build and operate the Arabian pipe line—and today exists in name only, with but one employe.

The Senator warned that many government corporations, through their loan-making or subsidy-paying operations, have become a factor in industrial and economic fields from which it will be difficult to oust them if prompt action is not taken.

Asserting that the language of its charter "reflects a definite purpose to engage the United States in the petroleum business, both at home and abroad, as a permanent industrial program," contrary to the intent of the statute under which it was created, Moore declared.

ACS Meeting Cancelled

The meeting of the American Chemical Society, scheduled for Chicago September 9 to 14, has been cancelled in keeping with a request of the Office of Defense Transportation.

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House Oil Committee May Study Gas Conservation

Many important studies are ahead for the oil investigating subcommittee of the House Interstate and Foreign Commerce Committee, the House was told March 20 as it passed a resolution continuing the life of the group.

The confidence of the House in this subcommittee, which has been conducting investigations since 1934, was indicated in the suggestion that it take steps to protect its jurisdiction against the House Small Business Committee, which has also investigated oil, and other committees which might like to get into that field.

Possible fields of activity for the oil subcommittee were outlined to the House by Representative Charles A. Wolverton of New Jersey, ranking Republican member. They include, he said: The question of whether there has been a serious depletion of domestic oil reserves; what policy should be adopted to encourage discoveries in order that there might be increased production; what should be the policy with respect to use of oil produced in foreign fields and the extent to which domestic oil may be exported for foreign use.

Wolverton pointed out that there are also related subjects which may come before the subcommittee, including prevention of waste of gas and the policy to be pursued with reference to war-emergency pipe lines.

During the debate there was no criticism whatever of the subcommittee, but a number of members commended the work it has done.

Excess Transportation and Stripper Costs Disclosed

Defense Supply Corporation's absorption of excess oil transportation costs has amounted to $301,345,000 since the program was initiated August 1, 1942, and will require a monthly expenditure of $11,000,000 through the year beginning July 1, next, while $11,301,000 has been paid out since August 1, 1944, in stripper well subsidies, which will cost $4,500,000 a month to maintain, according to figures submitted to a House appropriation subcommittee.

DSC income up to December 31, last, included $294,172,000 received under the plan for the equitable sharing of revenues and extra transportation expenses, $4,967,000 in reimbursement of loss on aviation gasoline, $77,340 in profit from alkylate operations in aviation gasoline and $183,755 profit on exchange of gasoline.

Rubber Reserve Company showed that losses due to enemy action cost $6,653,750.

Edwin F. Nelson Elected Universal Vice President

Edwin F. Nelson, head of the engineering and development department of Universal Oil Products Company, has been elected a vice president.

Nelson, who is a graduate in chemical engineering of the University of Wisconsin, joined the Universal organization in 1926. Through his work as a field engineer, in the research laboratories and on the pilot plants at Riverside, in the patent and engineering departments, and as assistant to J. G. Alther, executive vice president, he learned the cracking art and technique and the

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SOLÉCO *Steel* VALVES

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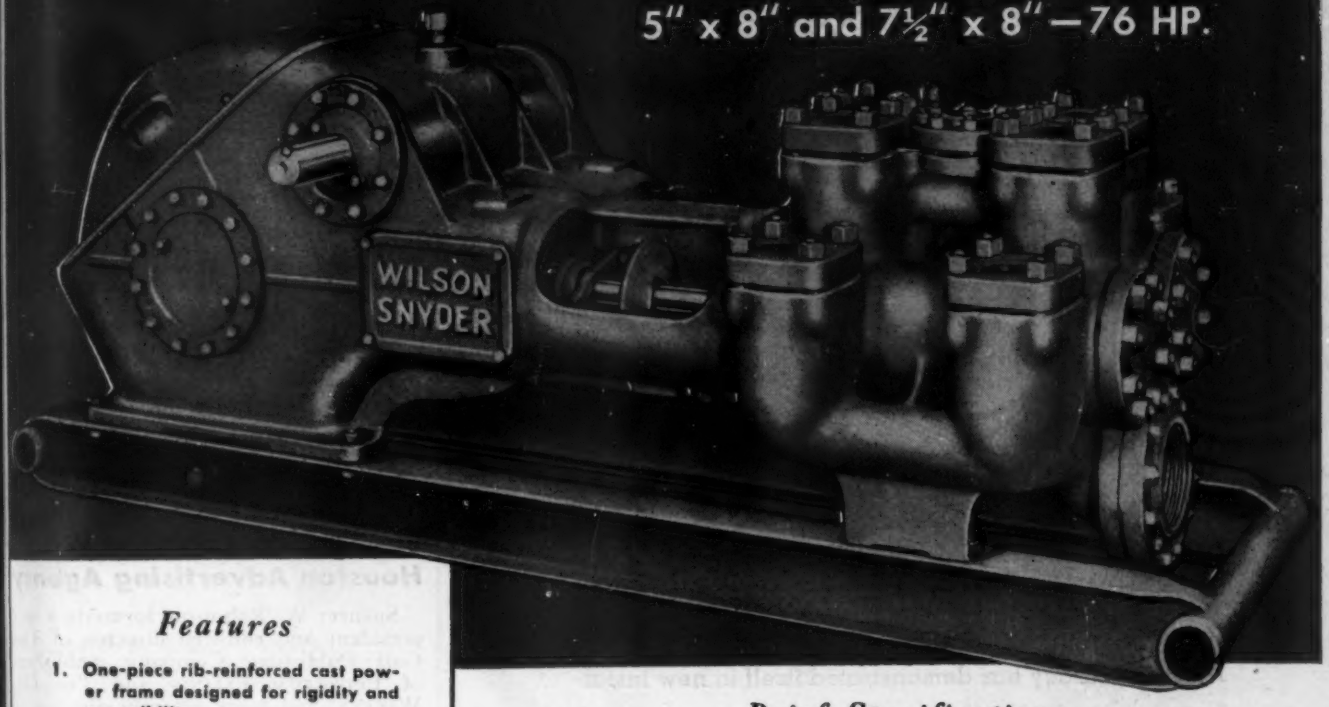
Power Driven Refinery Transfer and General Service Pump

5" x 8" and 7½" x 8" — 76 HP.



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6. One-piece direct-flow fluid end assures efficiency at all operating speeds.
7. Removable liners.
8. Right- or left-hand drive — pinion shaft can be reversed without disturbing main gear.

Brief Specifications

Size, Bore x Stroke (Duplex)	inches	5 x 8	7½ x 8
Liner Sizes	inches	3½, 4, 4½, 5	5½, 6, 6½, 7, 7½
Rated Speed	r. p. m.	80	80
Recommended Brake Horsepower at Rated Speed	. . . . .	76	76
Theoretical Displacement (Piston Rod Deducted with Full-Size Liners at Rated Speed)	g. p. m.	206	480
Maximum Working Pressure with Full-Size Liners	p. s. i.	540	230
Rated Fluid-Chamber Pressures: Suction	p. s. i.	900	200
Discharge	p. s. i.	1,800	400
Over-all Length (including Steel Skids)	. . . . .	8'10"	9'6"
Over-all Length (less Skids)	. . . . .	8'0"	8'3"
Over-all Width (including Pinion Shaft Extension)	. . . . .	3'2"	3'4"
Over-all Height (including Steel Skids)	. . . . .	3'2½"	4'2"
Weight Mounted Steel Skids: Domestic	pounds	5,175	5,500
Export	pounds	5,575	5,900

Additional information upon request.

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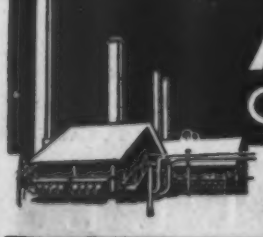

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EDWIN F. NELSON

operations of Universal and its licensees. When the commercial development department was established he was placed at its head. In 1938 the engineering and development departments were combined under his leadership.

Spencer W. Robinson With Houston Advertising Agency

Spencer W. Robinson, formerly a vice president and editorial director of The Gulf Publishing Company, publishers of PETROLEUM REFINER and THE OIL WEEKLY, and more recently director of public relations for Petroleum Administration for War at Washington, has joined Davis-Dyke & Company, Houston advertising agency specializing in copy and counsel for organizations selling to the oil industry.

SPENCER W. ROBINSON

VALVES

300-pound O. S. & Y. "Y" Valve, especially designed and built for handling hydrofluoric acid in alkylation plants. Has ring joint end flanges and body-bonnet connection. Equipped with Powell Patented Seat Wiper. This type of valve provides the straightway, full flow area of a gate valve plus the throttling feature of a globe valve.

To help meet the War's demands, especially for Synthetic Rubber and 100 Octane Aviation Gasoline, Powell Engineers have designed and introduced a line of valves made of pure metals and special alloys for use in Alkylation, Isomerization, Thermal Catalytic Cracking and the handling of Sour Crudes. The complete Powell Line includes valves of every design and material needed to meet the requirements of *all* refinery processes in use today.

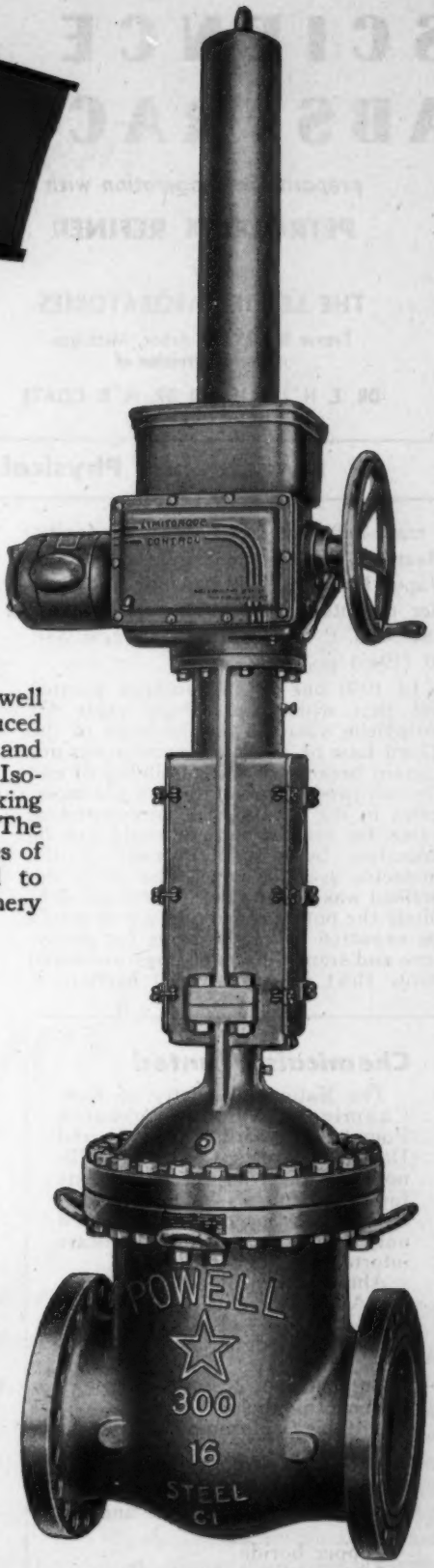

Fig. 3023—A 300-pound Cast Steel Gate Valve, Powell engineered for refineries producing 100 octane aviation gasoline. Top-mounted, fully enclosed, explosion-proof electric motor operator provides quick, positive opening and closing. Also has handwheel for manual operation.

Fig. 1097SW—Special Alloy Separable Body Reversible Seat "Y" Valve, especially adapted for handling hydrochloric acid in isomerization units. Provides straightway flow area through the body. Equipped with Powell Patented Seat Wiper for clearing seat and disc faces of adhering material, assuring a leak-proof metal to metal contact.

VALVES

SCIENCE AND TECHNOLOGY ABSTRACTS

prepared in cooperation with

PETROLEUM REFINER

by

THE LESLIE LABORATORIES

Traver Road, Ann Arbor, Michigan
under supervision of

DR. E. H. LESLIE and DR. H. B. COATS

The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by The Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical and Chemical Data

trans-2-Butene. The Heat Capacity, Heats of Fusion and Vaporization, and Vapor Pressure. The Entropy and Barrier to Internal Rotation. L. GUTTMAN AND K. S. PITZER. *Jour. Amer. Chem. Soc.* 67 (1945) pp. 324-27.

In 1940 one of the authors pointed out that while an entropy value for propylene obtained on the basis of the Third Law of Thermodynamics was uncertain because of the possibility of end for end random orientation of the molecules in the crystal, the corresponding value for trans-2-butene would not be uncertain because both ends of the molecule are the same. The study described was undertaken to establish definitely the potential barrier, which would be expected to be the same for propylene and trans-2-butene. Logs presented show that the potential barriers in trans-2-butene and propylene are approximately 2000 cal. per mole and that propylene molecules are oriented regularly in their crystals. Heat capacities of solid and liquid hydrocarbons are reported from 15 to 270°K. and vapor pressures from 200 to 274°K. The following values were obtained: melting point, 167.61 ± 0.05°K.; heat of fusion, 2331.9 ± 2 cal. per mole; heat of vaporization 5439 ± 15 cal. per mole at the boiling point, 274.04 ± 0.05°K.; and entropy of ideal gas at the boiling point, 69.12 ± 0.3 cal. per degree mole.

The Vapor Pressures of cis- and trans-Decahydronaphthalene. WM. F. SEYER AND C. W. MANN. *Jour. Amer. Chem. Soc.* 67 (1945) pp. 328-29.

The vapor pressures of cis- and trans-decahydronaphthalene were measured over a range of temperature from —30 to 223°C. The critical temperatures, latent heats and Trouton constant were calculated from the data. The data are presented in tabular and graphical form, and the apparatus and procedure are described in some detail.

The Solubility Relationships of High Molecular Weight Fatty Acids and Their Esters in Propane Near the Critical Temperature. D. A. DREW AND A. N. HIXSON. *Trans. Amer. Inst. Chem. Engrs.* 40 (1945) pp. 675-94.

The investigation reported was undertaken to determine the phase relationships of several of the fatty acids with liquid propane, and to test the use of this solvent as a medium for separating compounds of similar chemical and physical properties. Solubility curves for the binary systems of palmitic acid, stearic acid, and cetyl stearate in propane were determined. In all cases complete miscibility was found in all proportions from the melting point of the fatty acid or ester up to the critical solution temperature, which is near the critical temperature of propane. A comparison of the data for stearic acid with published data for oleic acid shows that the single double bond has practically no effect on the critical solution temperature with propane. A correlation developed from all available data shows that the critical solution temperature is dependent on the molecular weight, and that for aliphatic compounds of the types investigated, a minimum effective molecular weight of about 400 is necessary for a two phase region with liquid propane. A decrease of 1°C. in critical solution temperature is predicted for each additional methylene group in compounds of the type studied. The correlation indicates that the fatty acids are associated in double molecules in liquid propane, and that the effective molecular weight is twice the formula weight. The value of the correlation lies in the fact that it can be used, in combination with the ternary system data presented here and in other papers, to predict whether or not propane can serve as a selective solvent for high molecular weight aliphatic compounds. The data show that within the accuracy of the analysis, no separation of the two acids can be obtained with liquid propane, thus giving definite limitations to the use of propane as a selective solvent.

Chemicals Wanted

The National Registry of Rare Chemicals, Armour Research Foundation, 33rd, Federal and Dearborn Streets, Chicago 16, Illinois, has received urgent requests for the chemicals listed below. If anyone has one or more, even if only in one gram quantities, please inform the Registry.

Aluminum carbide
n-Amyl or higher n-alkyl maleate
n-amyl or higher n-alkyl fumarate
Butanediol-1, 2
Benzothiophene
9, 10-bis (Chloromethyl) anthracene 100 g
Any benzacridine (10-25 grams)
Butanone-2-01-4 and acetate
beta-Chlorallyl alcohol and esters
Copper boride
Any cyclic ketones of more than ten carbons
5-Chloropentanol-1
6-Chlorohexanol-1
N, N-Dibenzyl aniline
Diisobutyl ether
2, 3-Diamino terephthalaldehyde
Diethylene glycol monoethyl ether stearate and oleate
2-Fluoroethanol
2- or 3-Fluoro propanol
2-Nitrobutane
Neopentyl alcohol or acetate

Chemical Compositions and Reactions

The Structure of Spiropentane. J. DONOHUE, G. L. HUMPHREY AND V. SCHOMAKER. *Jour. Amer. Chem. Soc.* 67 (1945) pp. 332-35.

A pentane hydrocarbon was prepared by the debromination of pentaerythrityl bromide by Murray and Stevenson. To this they assigned the spiropentane structure on the basis of its Raman spectrum. The present authors have confirmed this structure on the basis of an electron diffraction study on the hydrocarbon. The spiropentane structure is of interest because in it the deviations of the carbon bond angles from the normal tetrahedral values are most severe, the central carbon atom in particular being subject to the double constraint of having two of its bond angles fixed at approxiately 60° by the three-rings of which it is the common member.

Classification of Crude Oils. K. G. MARGOSCHES. *Jour. Inst. Petr.* 31 (1945) pp. 1-8.

The author first reviews various classifications of crude oil as recorded in the literature, and then proceeds to a more detailed review of recent classifications. Among these are the U. S. Bureau of Mines classification based on the base of the crude oil. Eighty-five per cent of 800 crude oils analysed fell definitely in one of the three classes: paraffin, intermediate, or napthene base. Some of the

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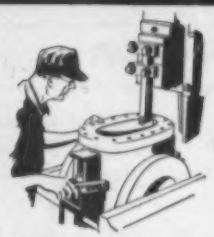

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factors used in classifying crude oils are viscosity index, characterization factor, characterization gravity, and, recently, correlation index. The characterization factor method was developed by the Universal Oil Products Company, and characterization gravity by the Standard Oil Company of California. The correlation index of H. M. Smith is discussed. A correlation index from 0-15 indicates that crude is predominantly paraffinic. An index above 50 indicates that aromatic rings predominate, and an index between 15 and 50 indicates napthenes or different mixtures of paraffins, naphthenes and aromatics. The decimal system as proposed by Voinov is briefly considered. A bibliography of 48 references is included.

The Catalytic Hydrogenation of the Benzene Nucleus. II. The Hydrogenation of Benzene and Mono-alkylbenzenes. H. A. SMITH AND E. F. H. PENNEKAMP. *Jour. Amer. Chem. Soc.* **67** (1945) pp. 276-78.

The authors investigated the kinetics of the catalytic hydrogenation of a series of mono-alkylbenzenes. The reactions were effected at low temperature, in acetic acid solution, using Adams platinum catalyst. First order reaction rate constants, all referred to one gram of standard platinum oxide, are given for 13 compounds. The relative rates of hydrogenation were compared with those previously obtained for a series of phenyl-substituted aliphatic acids, and also with a series of benzene hydrocarbons studied by Lozovoy and Diakova under considerably different experimental conditions. The factors influencing the relative rates of hydrogenation are discussed. The properties of the hydrocarbons and the components obtained from them are presented in tabular form.

The Catalytic Hydrogenation of the Benzene Nucleus. III. The Hydrogenation of polymethylbenzenes. H. A. SMITH AND E. F. H. PENNEKAMP. *Jour. Amer. Chem. Soc.* **67** (1945) pp. 279-81.

The authors investigated the kinetics of the catalytic hydrogenation of the polymethylbenzenes and of p-cymene. The reactions were effected at low pressures, in acetic acid solution, using Adams platinum catalyst. First-order reaction rate constants, all referred to one gram of standard platinum oxide, are given. It was demonstrated that, while increased methyl substitution generally decreases the rate of hydrogenation of the benzene nucleus, the position of substitution is also important. For compounds having the same number of methyl substituents symmetrically substituted ones react the fastest. The factors influencing the relative rates of hydrogenation of this group of compounds are discussed. Data are presented in some detail in tabular form.

Chlorinated Kerosene. R. M. DEAN AND E. LIEBER. *Ind. & Eng. Chem.* **37** (1945) pp. 181-85.

The chlorination of petroleum hydrocarbons and their utilization is becoming increasingly important and has received considerable impetus in recent times. Both the physical and chemical properties of the chlorinated products of lower-molecular-weight fractions have been extensively studied and re-

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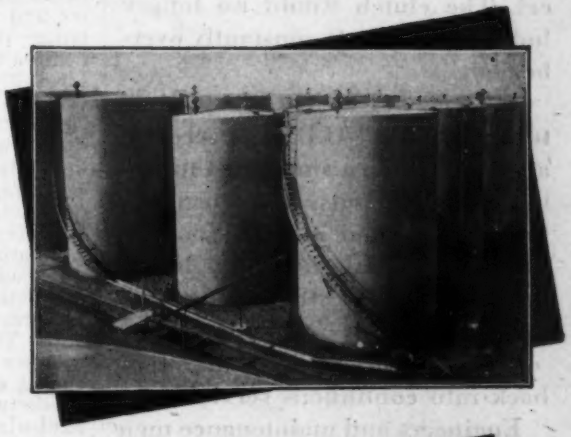

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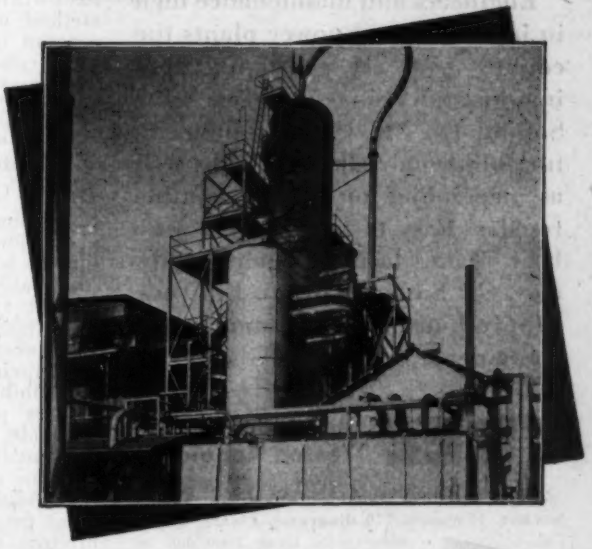

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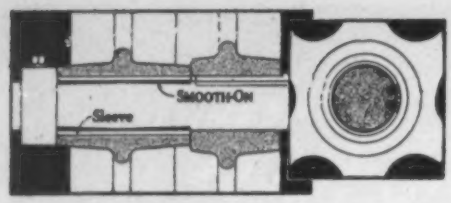

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corded in the literature, but not much can be found for the heavier fractions of petroleum, yet the latter group is more important industrially than the former. No systematic study has been reported correlating the physical properties of chlorinated kerosene with degree of chlorination. The object of the present investigation was to study a kerosene fraction boiling between 348° and 525°F. and chlorinated from 5 to 60% chlorine. Data taken included elementary analysis refractive index, surface tension, furfural points, kinematic viscosity, solid point, specific gravity, flash and fire points and molecular weight. These data were correlated with the degree of chlorination and the average molecular compositions obtained. Several derived values are presented including molecular refraction, molecular volume, and parachlor. These are correlated against atomic chlorine contents of the chlorinated products. The method of chlorination is described in some detail.

Manufacture: Processes and Plant

Comparing Fluids as Heat Transfer Agents. P. W. PARSONS AND B. J. GAFFNEY. *Trans. Amer. Inst. Chem. Engrs.* **40** (1945) pp. 655-73.

In selecting a heat transfer fluid the controlling factor is the relationship between the film coefficient of heat transfer and the energy consumed in circulating the fluid, the desired condition being a high value of the film coefficient for a low energy input. On this basis, water is superior to any of the organic liquids, sodium and mercury are superior to water, and air is of least value—inside tubes. Since, in designing a heat exchanger or selecting the optimum operating conditions for an existing exchanger, the total energy consumed in circulating the fluids, that inside the tubes as well as that outside the tubes, in relation to the overall coefficient of heat transfer is an important consideration. The authors give the relationships between the film coefficients and the energy expended in circulating the fluids inside tubes, both for the streamline and turbulent regions, for 21 fluids. A method of taking vapor pressure into account is also outlined. Other factors to be considered are: corrosion, fouling, weight of the fluid, and cost and availability of the fluid.

The Microbiological Aspects of Gasoline Inhibitors. F. H. ALLEN. *Jour. Inst. Petr.* **31** (1945) pp. 9-15.

Gasolines are stabilized against gum and color formation, and the precipitation of tetra ethyl lead by the addition of suitable substances known as inhibitors or anti-oxidants. These substances were first described in 1922 and were introduced in England in 1926. Since 1929 their use has been general. Gasoline inhibitors apparently exert their effect by preventing initial formation of peroxide. A new theory is presented to account for the delay in deterioration of gasoline and aviation fuels produced by the addition of inhibitors. The bactericidal properties of the commercial inhibitors are noted. Data are presented to show that these inhibitors are strongly adsorbed at the gasoline-water interface where they are able to exert their greatest bactericidal activity. The microbiological aspects of inhibitor intensifiers and metal deactivators are also discussed. This biological concept of gasoline inhibitors is intended to supplement the extensive chemical research that has been conducted on the deterioration of gasoline motor fuels in storage. Recent studies have shown conclusively that various microorganisms in the water phase normally present below gasoline motor fuels in storage have a pronounced deteriorating effect on the motor fuel. Bacterial activity was found to result in greatly increased formation of peroxide and gum in motor gasoline and in precipitation of lead tetra ethyl from aviation gasoline. A bibliography of 23 references is included.

Gas Absorption as a Function of Diffusivities and Flow Rates. E. G. SCHEIBEL AND D. F. OTHMER. *Trans. Amer. Inst. Chem. Engrs.* **40** (1945) pp. 611-53.

A general equation is presented for expressing the coefficient for the absorption of any solute vapor from air by water on 10-mm. glass Raschig rings. The same general form of equation was found to correlate coefficients on 1-inch Raschig rings. The equations indicate that the liquid film coefficients are not affected appreciably by the increase of the amount of surface of the packing per cubic foot, while the gas film coefficient increases with such an increase. The absorption of four methyl ketones by water was studied, and individual film coefficients were found to be proportional to the 0.8 power of the fluid rates. Based a direct proportionality of the film coefficients to diffusivities, the present formula checked the work of other investigators on solutes having diffusivities three times as great as those used in the present work. The data give some indications that the mass transfer coefficients for the four different methyl ketones vary directly with concentration; and this effect of concentration appears to be greater for systems having large activity coefficients.

Liquid-Liquid Extraction in a Perforated Plate Column. R. W. MOULTON AND J. E. WALKEY. *Trans. Amer. Inst. Chem. Engrs.* **40** (1945) pp. 695-707.

Most of the investigations of liquid-liquid extraction have been concerned with ideal systems in which the simple distribution law is valid. The system studied by the authors was non-ideal in that the simple distribution law was not applied and the volume changes of the two phases throughout the column were large. Equilibrium distribution data are reported for the system: 2,2,4—trimethylpentane-methyl ethyl ketone—water and the system: gasoline—methyl ethyl ketone—water at 25°C. Methods of analysis are described. A 3.75-in. in diameter perforated plate countercurrent liquid-liquid extraction column was operated for the extraction of methyl ethyl ketone from mixtures of gasoline and methyl ethyl ketone corresponding to the azeotropic distillate formed in the system: toluene—gasoline—methyl ethyl ketone. The operating behavior of the tower was evaluated, and the plate efficiencies are reported for this non-ideal system. The ratio of the solvent rate to

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Asphaltic Products from Petroleum Extracts. P. V. McKinney, M. G. Mayberry, and H. E. Westlake, Jr. *Ind. & Eng. Chem.* **37** (1945) pp. 177-78.

The reaction of sulfur with solvent extracts from petroleum lubricating stocks leads to the formation of an asphaltlike solid the hardness of which is much less dependent on temperature than is usual for such asphaltic materials. It is of promise as a filler for joints and in caulking. Sulfur is only slightly soluble in the extract. However, above 140°C. a reaction occurs with the evolution of hydrogen sulfide. The nature of the reaction products depends on the character of hydrogen sulfide. The nature of the reaction products depends on the character of the petroleum extract as well as on the conditions of treatment. Extracts having a Saybolt viscosity lower than 340 seconds at 210°F. give unsatisfactory products; those with greater viscosity yield tough plastic solids. The extract is heated, with stirring, in an open vessel. At 120°C. the sulfur is added and the mixture stirred vigorously. As foaming decreases the temperature is raised to 170-180°C. After 6-8 hours of stirring at this temperature, the foaming subsides and a suitable product results. The products are tough, black, asphaltlike solids. About 10% is free sulfur that can be extracted with sodium sulfide. Estimates indicate that the new product can be manufactured at costs that permit competition with the best grades of asphalt. Experimental expansion joints on the roof of Mellon Institute have revealed no evidence of leaking or exuding after four years. The properties of the raw materials are presented in tabular form, as well as the properties of the reaction products.

Agitation of Two-Phase Systems of Immiscible Liquids. S. A. Miller and C. A. Mann. *Trans. Amer. Inst. Chem. Engrs.* **40** (1945) pp. 709-45.

The authors investigated the effect of several design variables on the power characteristics and performance of agitators operating in various water-oil mixtures, as well as in homogeneous liquids. The power required to agitate a system of two immiscible liquids can be correlated by a power function—Reynolds number plot, if the average density of the mixture and a weighted geometric mean of the viscosities of the two phases are used in calculating these functions. Degree of mixing, evaluated by a sampling scheme, are reported in terms of the Hixson-Tenney mixing index, modified to suit the conditions of this investigation. The effects of liquid depth, agitator clearance, interface level, and oil-phase properties on the degree of mixing and the power requirement of each of the impellers are evaluated. It is shown that laboratory tests of the agitation of two-phase liquid mixtures can be scaled up by designing larger equipment that is geometrically similar to that used in the laboratory and by applying equal power per unit volume in both sizes.

Products: Properties and Utilization

Selecting the Best Lubricant. E. V. Patterson. *Petroleum* (London) **7** (1944) pp. 220-21.

In general, service tests are best for selecting a lubricating oil. However, it is frequently impossible to arrange service tests. The author has prepared a chart for various types of machines that will provide engineers with a method for selecting oil. The oil is given 100 points, to be divided among the tests regarded as important. The best oil will be the one having the highest average rating number. The author admits that the chart falls short of the ideal, but feels that it is useful, not only for selecting the best oil but for pre-selecting the best oil for more detailed and accurate testing. The tests included in the chart are: acidity, carbon content or residue, pour point, demulsibility, flash and fire points, resistance to oxidation, specific gravity, specific heat, viscosity index, and volatility. The services covered are gasoline and diesel engines, gas engines, air compressors, steam engines, bearings, spindles, transformers, refrigerating machines, and turbines.

Bearing Corrosion Characteristics of Lubricating Oils. C. M. Loane and J. W. Gaynor. *Ind. & Eng. Chem., Anal. Ed.* **17** (1945) pp. 89-95.

The only practical correlation of the corrosion characteristics of lubricating oil is that between laboratory tests and standard accelerated engine tests. The investigation reported was limited to a comparison of laboratory corrosion tests with Chevrolet 36-hour tests. The laboratory method used was a modification of the Indiana stirring oxidation test. The study was concerned not so much with the test method as with the conditions under which the tests were run, particularly as regards catalysts used. The Indiana stirring corrosion test method is described in some detail. The seven oils were selected to represent a wide variety of additives and to give Chevrolet test corrosion results ranging from very poor to very good. The authors are of the opinion that lead test specimens should be used in a laboratory test in which the bearing is not mechanically rubbed. The effect of various solid catalysts varies widely depending on the type of additive in the oil. Lead oxide would appear to be an appropriate catalyst for use where correlation with the Chevrolet 36-hour test is desired. Such a correlation has been established using 5.5% lead oxide as catalyst. The Chevrolet test is extremely severe, and it is probable that oils that pass it will give satisfactory performance in ordinary heavy duty service where leaded fuel is used. Oils that do not pass this may or may not give satisfactory performance in such service. The interpretation of the corrosion test is discussed, with possible explanations of variations observed.

Nature of Asphaltic Substances. D. L. Katz and K. E. Beu. *Ind. & Eng. Chem.* **37** (1945) pp. 195-200.

The electron microscope has been found to be a useful tool in making

studies of the physical state of asphaltic substances. Crude oils, as well as a series of products such as topped crude, reduced crude, on through the various grades of asphalt have been examined. Experiments have given a concept of the state of the asphaltic substances in crude oil and refined products that is somewhat at variance from the views previously held. Based on hundreds of observations the authors believe that asphaltene does not occur as a micelle with a diameter greater than 65 Å. The maximum number of molecules represented by an asphaltene particle when assuming a minimum molecular weight of 1000 would be 90. It therefore appears just as logical to describe asphaltene when present in crude oils as negatively charged molecules or small groups of associated molecules as to call them "colloidal particles". The asphaltene could be said to be insoluble in solvents and, hence, precipitable from solutions in petroleum ether, benzene, carbon disulfide, or pyridine. One view could be that the asphaltenes are potential colloids and that solutions containing them easily convert into colloidal systems from changes in the composition of the solution or from electrical effects. The article is illustrated with figures presenting typical micro photographs, and includes a bibliography of 16 references.

The Analysis of Liquefiable Hydrocarbons by Distillation. Liquefied Gases Panel of Sub-Committee No. 3. *Jour. Inst. Petr.* **31** (1945) pp. 16-22.

A panel of Sub-Committee No. 3 of the Standardization Committee of the Institute of Petroleum has been concerned for some time with methods for the examination of Petroleum gases. The committee concluded that it was neither practicable nor desirable at the present time to attempt to standardize any particular form of apparatus or to set forth in detail procedure for determining these light hydrocarbons. In the meantime it was regarded as desirable to formulate a general procedure that could be applied to any reliable method of distillation analysis, and to agree on the best available data for the boiling points and densities of the hydrocarbons for use in calculation. The method described is therefore published for the purpose of information. Apparatus and procedure are outlined, including precautions deemed necessary to take to secure accurate results. The boiling points of the lower paraffins and olefins are tabulated. Distillation rates are prescribed. A method of calculating the results is outlined. To obtain the results as liquid volume percentages at 60°F. the specific gravities at 60° of the hydrocarbon are given in a tabulation.

Detection of Diene Hydrocarbons with a Conjugated Double-Bond System. III. V. I. Esafov. *J. Applied Chem.* (U.S.S.R.) **16** (1943) pp. 283-95 (English summary).

The reaction of bromination in carbon tetrachloride is specific only for those dienes that have 1, or better 2 side chains connected to carbons of the conjugated system. In this case considerable HBr is evolved and 50-60% of bromine is used for the side reactions. Di- and tri-isobutylenes are characterized by this behavior. The iodination reaction is specific for dienes of normal and branched structures and these are characterized by some 88% conversion

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of iodine into HI by the side reactions. The iodine number procedure of Hubl-Waller is most accurate for determining unsaturation.

Analysis of Ternary Mixtures Containing Nonconsolute Components. A. S. SMITH. *Ind. & Eng. Chem.* **37** (1945) pp. 185-87.

An indirect method of analysis for liquid mixtures of three components is described. It is applicable to ternary systems having a miscibility gap. The method requires determination of two saturation points on a solubility isotherm of the ternary by addition of two of the components to the unknown mixture. The composition of the original mixture is then obtained by graphical or algebraic calculation. The method is applied to a specific example of a mixture of methylethylketone, carbon disulfide and water.

Mass Spectrometry. H. W. WASHBURN, H. F. WILEY, S. M. ROCK, AND C. E. BERRY. *Ind. & Eng. Chem., Anal. Ed.* **17** (1945) pp. 74-81.

During the past two years the mass spectrometer has graduated from being a piece of laboratory apparatus to an industrial instrument. It is now used for refinery control as well as to handle special analytical problems encountered in refinery operation, and is employed in process development and other chemical research. The authors give a brief historical sketch of the subject and indicate the types of analyses to which the instrument is well adapted. Its specific application to refinery control is described. The observed experimental correlation between mass spectra and structure of hydrocarbon molecules is illustrated by the spectra of the octanes. The large variations of spectra with minor variations in arrangement of atoms in a molecule are responsible for the application of the mass spectrometer to analysis of isomeric paraffin hydrocarbon mixtures containing as many as ten components. The analysis of a mixture from its mass spectrum can be obtained from the solution of linear simultaneous equations. However, in samples contained in the C_1 to C_8 hydrocarbons, many components or groups of components can be determined from mass spectrum peaks that receive no contribution from other components in the mixture. This is particularly true when the peaks referred to are corrected for the presence of heavy isotope. The resulting simplifications in computing the analyses are illustrated by specific examples. The instrument and its method of operation are briefly described.

Thorium Nitrate Titration of Fluoride. M. P. MATUSZAK AND D. R. BROWN. *Ind. & Eng. Chem., Anal. Ed.* **17** (1945) pp. 100-106.

The method described is an outcome of research directed to the use of fluorine-containing catalysts. Although developed primarily to meet the need for determining up to 0.1% of organically combined fluorine in hydrocarbons, such as those present in various stages in the manufacture of aviation gasoline by hydrofluoric acid alkylation, the method should prove useful for the analysis of many other materials. In comparison with earlier thorium nitrate methods of determining fluoride, it possesses advan-

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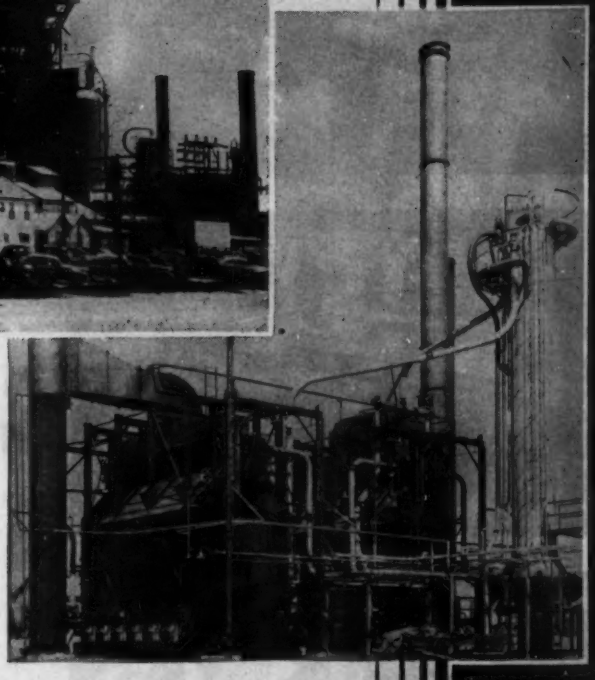

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tages of simplicity, wide range, accuracy, and reproducibility. Also, it determines with reasonable accuracy another acid-forming element, such as sulfur or a halogen other than fluorine. The procedure involves conversion of the fluorine or sulfur in a sample into an aqueous solution of fluoride and sulfate, and determining the total acid equivalent to the fluoride and the sulfate, determining the fluoride by titration with thorium nitrate under selected conditions, and calculating the sulfur after deducting from the total acid the part equivalent to the fluorine. The method is described in some detail, and the data secured in the course of the work are presented in tabular and graphical form. A bibliography of 26 references is included.

Book Review

Asphalts and Allied Substances

By Herbert Abraham, D. Van Nostrand Company, 250 Fourth Avenue. Fifth Edition, in two volumes, 2142 pages. Price $20.

The original work was published in 1918, and this Fifth Edition has been revised and brought up to date in respect to technological developments, methods of testing, and greatly enlarged bibliography and references.

This book contains data for those interested in production, merchandising and application of all bituminous products. For technical readers, and particularly those within the refining industry, there is a chapter on "Chemistry of Bituminous Substances," and on "Methods of Testing." also there is data on blending and compounding mixtures for the numerous special uses to which asphalt is put.

A section on pyrogenous asphalts and waxes discusses petroleum refining processes from which come asphalt as a by-product, and subsequent refining and processing of this product for commercial use. The bibliography on this section is extensive, as is the catalog of patents dealing with asphalt refining.

Bureau of Mines Reports Available

Two reports of investigations of the United States Bureau of Mines, previously restricted because of military necessity, are now available. One is R. I. 3701, "Evaporation Losses of Aviation Gasoline in Standing Storage," by Peter Grandone, associated petroleum engineer at the Bartlesville Station. The other is R. I. No. 3729, "Effects of Desulfurization on the Lead Susceptibility of Distillates from Some Crude Oils from Texas, New Mexico and Oklahoma," by Boyd Guthrie and M. C. Simmons, chemist and assistant petroleum engineer at the Bartlesville station.

The report on evaporation losses of aviation gasoline was printed in 1943 but restricted at the time for security reasons. This work involved experiments of storing gasoline in a 55,000-barrel tank with cone roof as well as experiments of storage in a tank of equal size but with modified breather roof. Other tests were made on losses from storing blending stocks for aviation motor fuels.

The work on lead susceptibility was

DESPITE *given crude sources* and *established markets*... refinery managements and their engineering staffs do not have a simple task in reaching decisions on postwar remodernization plans.

After due study of process recommendations and proposed capital investments . . . ticklish questions remain to plague. Is the plan sufficiently elastic to provide for envisioned product improvements? Does it provide the shortest pay-off period? Will current equipment be utilized to the fullest advantage?

It is here that the full scope of M. W. Kellogg's complete service is most appreciated—and valued—by customers. For this service embraces more than that of designer-builder. It shoulders the direct responsibility to the refiner of translating plant operations into maximum profits.

Supplementing and integrating the customer's management and engineering staff planning... Kellogg brings the full weight of its process design, pilot plant data, diversified outside commercial experience, and economic consultation services to bear on the specific problem involved.

Invariably, with increased profits as the goal, not one but several solutions present themselves. But for *maximum* profits . . . there is only *one!* For instance, in a recent case study, exhaustive analysis disclosed three different potentially profitable solutions.

Case A showed a 205% increase over existing yearly net credit... with a pay-out period for remodernization of 3.84 years—amortizing capital investment exclusively from the *increase* in annual credit.

Case B, on the other hand, showed an increase in yearly net credit of 263% (a further increase of 58%). In addition, it provided a shorter pay-out period—3.39 years—notwithstanding a 13% greater increase in capital expenditure.

Case C offered the same fundamental advantages as B . . . with a different choice of by-products.

Such detailed explorations of a client's problems demonstrate the responsibilities that M. W. Kellogg assumes over and above those of mere designer-builder. May we consult with you on your current plans?

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★**METALLURGICAL LABORATORY**—Establishes continuous check of specifications...creates new techniques for the fabrication of refining equipment.

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★**OPERATING STAFFS**—Specialists at placing new units "on stream"... training of refiner's own operating crews.

★**LICENSING SERVICE**—Licenses available through Kellogg as Licensor or licensing agent for all types of refining processes.

★**ECONOMICS CONSULTATION**—Offers oil companies the opportunity to have their overall operations reviewed and evaluated by personnel with authoritative and extended experience in the field of petroleum economics and management.

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You can entrust your requirements for towers, scrubbers, condensers, liquid and gas tanks, etc., to Stacey Brothers with full assurance of satisfaction. Estimates gladly furnished. Send us blueprints or specifications of your requirements.

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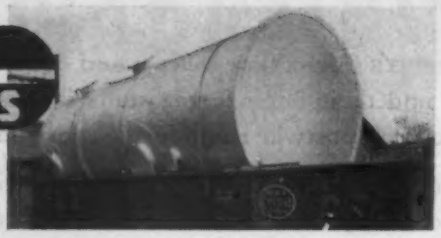
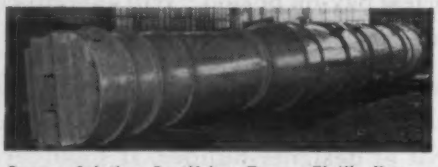
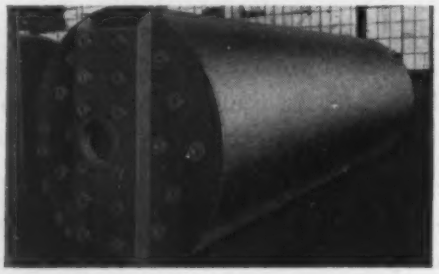


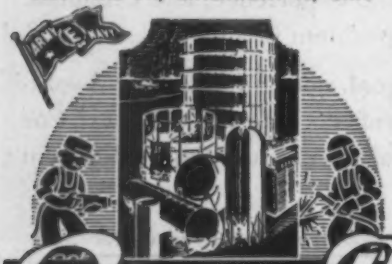
Special Heating Tower, 10'-0" diam. x 30'-0" high. Includes spray system and grids. Wt. 27,000#.



Copper Solution Rectifying Tower, 7'-6" diam. x 61'-0" high. Shipped as completed unit. Wt. 50,000#.



Ammonia Scrubber, 11'-0" diam. x 30'-0" high. Shipped as completed unit. Wt. 30,000#.



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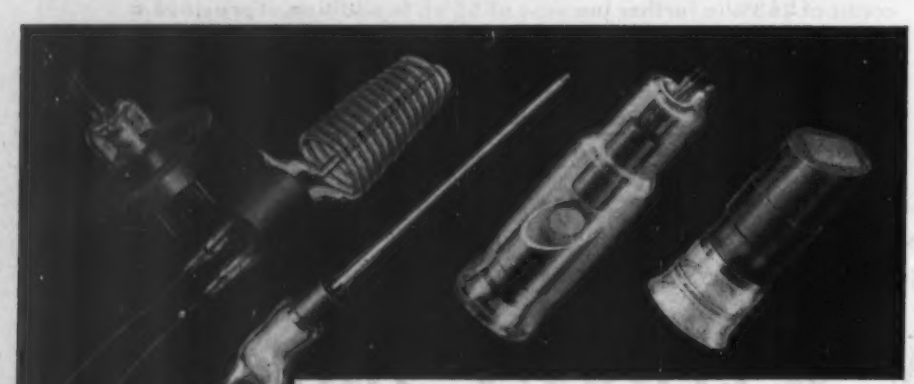

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published in November, 1943. Along with other data it contains an extended ethyl blending chart.

ASTM Develops Tests For Aromatic Hydrocarbons

Several proposed testing procedures and specifications for industrial aromatic hydrocarbons have been developed by ASTM Committee D16, organized in 1944. Subcommittees have carried out work on test methods for crude and refined aromatic products and specifications for aromatic chemicals and solvents.

Methods of Test for Crude Aromatic Products—Determining refined water-white constituents in light oil.

Methods of Test for Refined Aromatic Products—Scope, specific gravity, hydrogen sulfide and sulfur dioxide; color; copper corrosion test; distillation(aromatic hydrocarbons); acid wash (benzene. toluene, xylenes, and similar materials); solidifying point (benzene); paraffins; acidity.

Specifications for Aromatic Chemicals—Nitration grade benzene; industrial grade benzene; nitration grade toluene; industrial grade toluene; nitration grade xylene; 5° xylene.

Specifications for Aromatic Solvents—Industrial 90 benzene; 10° xylene; industrial xylene; refined solvent naphtha; crude light solvent naphtha; crude heavy solvent naphtha.

The committee is eager to stimulate constructive comment, based on practices in current use. Copies of methods and specifications may be obtained from the acting secretary, W. L. Douthett, The Texas Company, 135 East 42nd St., New York 17, New York. J. M. Weiss is chairman of the committee.

Ashland Buys Kentucky Plant from Texas Company

The Texas Company's refinery at Pryse, Kentucky, has been acquired by Ashland Oil & Refining Company, in a deal which included producing properties and pipe-line facilities in Eastern Kentucky. The refinery has a daily crude-oil capacity of 5,000 barrels, and 2,000 barrels cracking capacity. Ashland Oil & Refining Company has a 20,000-barrel refinery at Catlettsburg, Kentucky.

Seek Year Extension of Government Subsidies

A one-year extension to June 30, 1946 of subsidy payments by the United States government on oil and other commodities has been given approval by the Senate banking and currency committee. Representatives of Reconstruction Finance Corporation, Office of Price Administration and other agencies appeared during a brief hearing.

All subsidies, which officials of the agencies dispensing them say are needed to prevent inflation, will amount to $1,500,000,000, of which $290,000,000 goes for oil payments. Of the latter amount, $150,000,000 is extra cost of transportation to the East Coast; $20,000,000 for extra cost of transportation to the Middle West; $45,000,000 for excess cost of using West Texas oil in California refineries, and $75,000,000 for stripper-well premium payments.

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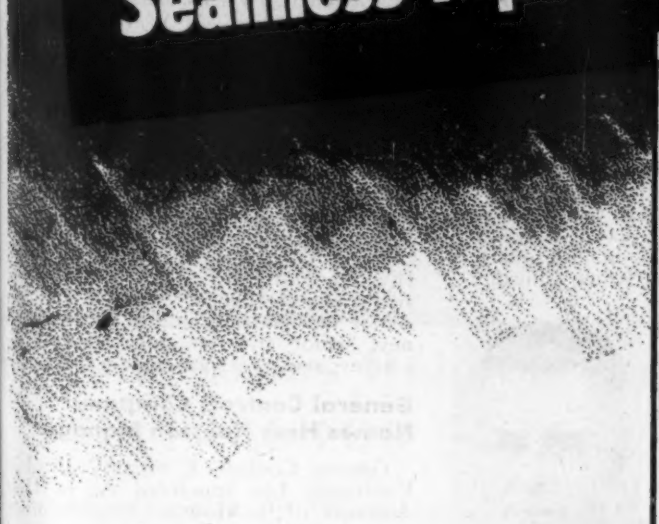

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About EQUIPMENT—SERVICE Suppliers

Duffy Made Assistant Sales Manager for Pennsylvania Salt

Pennsylvania Salt Manufacturing Company, Philadelphia, has advanced J. J. Duffy, Jr., to assistant manager of sales. A chemical engineer, he has been associated with the company since 1937, starting as sales-service engineer for the special chemicals division in New York state. Since 1942 he has been in the Philadelphia office as development and service engineer on new products of the special chemical division made necessary by wartime needs of industries served by that division.

J. J. Duffy, Jr.

American Chain & Cable Promotes E. J. Flood

E. J. Flood has been appointed general district sales manager for the Chicago sales territories of American Chain & Cable Company. He has been with the company for 25 years in the Page Steel and Wire, and American Chain Divisions, and will continue his headquarters at 400 West Madison Street, Chicago.

Baker Manager of Lagonda Division

V. H. Baker has been appointed plant manager and product engineer for Lagonda Division of Elliott Company, Springfield, Ohio. Baker has been associated with Elliott Company for 35 years.

V. H. Baker

Prufcoat Laboratories Opens Branch Office in New York

Prufcoat Laboratories, Inc., Cambridge, Massachusetts, has opened a branch office at 50 East 42nd Street, New York, with David E. Long in charge of sales and service engineering.

A. O. Smith Corporation Opens Export Office in New York

New York offices for A. O. Smith Corporation's International Division have been opened in the Commerce Building, New York, with A. E. Cripps, newly-appointed Eastern supervisor, in charge.

In addition to handling the company's export activities in New York, Cripps will supervise lend-lease and foreign government business in Washington.

Cripps was born in England, attended King's College and London University, and was a captain in the Royal Flying Corps in World War I. He came to the United States in 1919, became a citizen in 1928, and has been associated with American Smelting & Refining Company, Black & Decker, and was foreign manager of John A. Roebling Sons & Company for 13 years.

Chemical Fire Extinguisher Association Re-elects

Chemical Fire Extinguisher Association, in annual meeting at Chicago on March 8, re-elected the following officers: Arthur G. Sullivan, Buffalo Fire Appliance Corporation, president; J. O. Binford, American-La France-Foamite Corporation, vice president; Herman W. Diener, George W. Diener Manufacturing Company, treasurer, and W. J. Parker, W. J. Parker, Inc., commissioner. Directors re-elected are George H. Boucher, Pyrene Manufacturing Company, and E. A. Warren, General Detroit Corporation.

Pennsylvania Salt Advances Woodard in Engineering Staff

Pennsylvania Salt Manufacturing Company recently announced promotion of A. S. Woodard to asistant chief engineer, which was effective January 1. Previously he had been senior chemical engineer. Other appointments announced, effective March 1, include J. P. Evans, senior electrical engineer; R. R. Walden, senior mechanical engineer; P. F. Dorney, senior civil engineer, and J. W. Dadley, senior design engineer.

General Controls Company Names Hess Houston Manager

General Controls Company, Glendale, California, has appointed A. E. Hess manager of its Houston branch office, serving Southern Texas, Lousiana and Southern Mississippi. Hess has been with the company since early in 1944, and before that had many years experience in the engineering field with The Carrier Corporation and Johnson Service Company, and also spent several months on special engineering duty for the United States Navy.

Hanlon-Waters and McAlear Become Division of Climax

Hanlon-Waters, Tulsa, and McAlear Manufacturing Company, Chicago, have integrated their operations and will conduct business as Automatic Control Division of Climax Industries, of which Climax Engineering Company also is a division. These three companies, affiliated for the past year, have been operated as separate businesses.

L. J. Griffey

General management, engineering and sales are being

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centered under single heads in charge of these executive functions for Hanlon-Waters and McAlear plants, for which Edward F. Deacon, president of Climax, has announced the following appointments: L. J. Griffey, vice president and general manager, M. C. Waterman, vice president in charge of engineering, and C. W. Snyder, vice president in charge of sales.

The two plants and all Hanlon-Waters branch offices and warehouses in the Mid-Continent will be continued, and sales in other territories will be handled by distributors. Export sales will be handled by General International, Chicago.

Worthington Appoints Steven Executive Engineer at Buffalo

Worthington Pump and Machinery Corporation announces appointment of George Steven as executive engineer of its Buffalo Works. Harold W. Whiting, formerly Steven's assistant, succeeds him as chief engineer of Buffalo Works Conpressor Division.

Foxboro Company Engineer Assigned to Corpus Christi

The Foxboro Company has announced appointment of William A. Rock as its resident engineer for the Corpus Christi area, under direction of its Houston office. Rock has spent most of his life in the Southwest and his business experience has been principally in the instrumentation of oil refineries and gasoline plants. Through association with construction companies he has had extensive training in installation, operation and maintenance of instruments used in oil operations.

Chicago Bridge & Iron Company Reopens Office at Los Angeles

Chicago Bridge & Iron Company recently has reopened its office at Room 1105 William Fox Building, Los Angeles, with Dean E. Stephan in charge. Stephan for the past several years has been assistant to James C. Vosburgh, manager of the company's office at Washington, and before that was a member of the sales staff at Birmingham.

Steel Improvement Names Graves Sales Manager

W. E. Graves has been appointed sales manager of The Steel Improvement & Forge Company, Cleveland. He has been with the company five years, and recently has been in charge of priority and traffic matters. The company also has appointed R. A. B. Williams, 216 Professional Building, Los Angeles, its representative for the Pacific Coast States.

Returned Service Men Accept Honor for Brown Instrument

The fourth Army-Navy E award presented to The Brown Instrument Company was accepted by a group of returned war veterans on behalf of their fellow workers and the management. These men were selected because the management felt they represented both the fighting men in the armed services and workers on the home front.

Pittsburgh, Merco Nordstrom Appoint Two Service Engineers

Pittsburgh Equitable Meter Company —Merco Nordstrom Valve Company has added William H. Johnson and George L. Guess to its force of service engineers working out of its New York district office. They will handle sales and service of Pemco and Merco products in a territory which includes most of New York state and all of New Jersey.

Johnson has been connected with the manufacture of water meters and water meter parts for the past 15 years. Guess has been with the company for several

G. L. Guess

W. H. Johnson

For strength and simplicity, only two parts are used — bearing bars which carry the load and have curved slots punched ABOVE THE NEUTRAL AXIS, and cross bars, of the same cross sectional area as the slot itself, pressed into these slots to distribute the load. No rivets, bolts or welds are required, thus eliminating the possibility of loose joints. Tri-Lok flooring comes in rectangular, diagonal and U shapes with Safety Steps — ask for Bulletin 1140 — DRAVO CORPORATION, NATIONAL DEPARTMENT, 300 Penn Avenue, Pittsburgh (22), Pa. (Distributor for THE TRI-LOK COMPANY)

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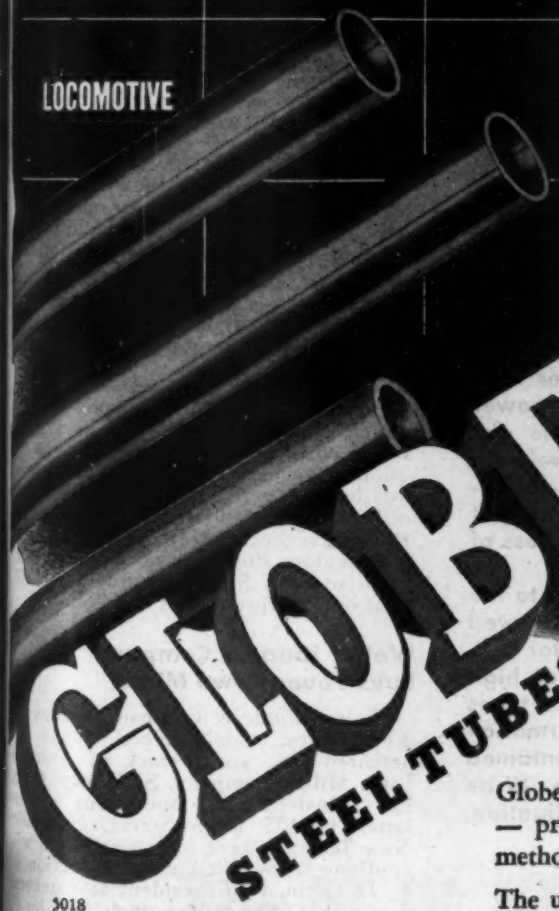
			RECTANGULAR	ROUND	SQUARE



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GLOBE STEEL TUBES

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GLOBE TUBES

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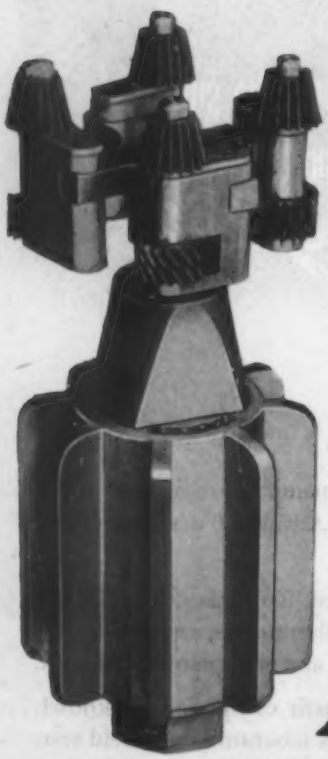
There is more than enough power in a Wilson Tube Cleaner to remove hard coke and tar deposits even in the largest refinery tubes.

This is shown by the fact the the E. P. Heavy Duty Motor is often smaller in diameter than the I. D. of the tube to be cleaned. Power in tube-cleaners is a function of their diameters—the reason that many motors must be as large as the tubes in which they are used. If the Wilson E. P. Heavy Duty Tube Cleaner Motor were made as big as a large diameter tube permits, it would have too much power for convenient use. Therefore, the ribs shown on the 6" I. D. cleaner above were added to bridle that extra power—to permit the use of a motor developing just the right amount of power regardless of tube size.



Available in sizes from 6 I. D. to the largest ever used in straight or curved tubes, the E. P. Heavy Duty Motor provides a smooth flow of power at high torque for fast, easy removal of all types of refinery deposits. Complete information on this unusual tube-cleaner is contained in the 40-page Wilson catalog. Write for your copy today—without obligation.

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years, covering part of New York state. In his new assignment he will cover the same territory plus some new area. His experience before his present connection included conducting his own industrial lighting and equipment business.

James M. Tuttle Joins Foxboro at Pittsburgh

The Foxboro Company, Foxboro, Massachusetts, announces appointment of James M. Tuttle to the staff of engineers attached to its Pittsburgh office, 5151 Baum Boulevard. Tuttle is a graduate of Massachusetts Institute of Technology, spent several years as an engineer with an industrial construction company, and later conducted his own business as a manufacturers' representative and engineering consultant.

Dresser Industries Opens New Cleveland Headquarters

New centralized administrative offices of Dresser Industries, Inc., formerly at Bradford, Pennsylvania, have been opened at 1130 Terminal Tower, Cleveland. Members of the group, now numbering 13 units, also have centralized domestic and export sales offices in New York, at 800 Channin Building.

Ohio Injector Company Gets Fourth Star for E Flag

Ohio Injector Company, Wadsworth, Ohio, has been awarded the fourth star for its Army-Navy E. Originally this company was given the award in July, 1942, one of the first of such ceremonies to be broadcast over a national radio chain. Subsequently the company has maintained its production record for the additional recognition.

General Detroit Corporation Opens Dallas Warehouse

General Detroit Corporation, fire extinguisher division, has opened a new branch office and warehouse at Dallas, Texas, with S. M. Luce in charge as division manager. This branch will handle distribution of the company's products in the South and Southwest, and supplements branches at New York, Chicago, Washington, Boston, Los Angeles, San Francisco and Seattle, supplying 22,000 local outlets throughout the country.

Walter Kidde & Company Buys Youngstown Miller

Walter Kidde & Company, Belleville, New Jersey, which several weeks ago acquired the capital stock of Youngstown Miller Company, Sandusky, Ohio, has transferred all operations of the latter to 675 Main Street, Belleville, New Jersey, where orders on hand will continue to be filled under direction of F. L. Gerin, vice president and general manager. Other officers include John F. Kidde, president, Harold A. Cartier, vice president, G. Crosby Hiss, secretary, and William Deyerberg, treasurer. R. E. Strobel continues as sales manager for Youngstown Miller products.

Youngstown Miller Company for the past 10 years has manufactured batch reclaimers for all types of lubricating, hydraulic, and cutting oils. Recently it developed the "Robot" refiner for continuous cleansing of large quantities of oil in constrant process use. Other products which the company will continue to manufacture and sell include a com-

HEAT TRANSFER EQUIPMENT *by* KELLOGG

Kellogg-designed and Kellogg-built heat exchanger and condenser equipment contains that Kellogg "know-how" which assures efficient, economical and long lived operation under the most difficult operating conditions.

Kellogg engineers, for years have been actively engaged in solving heat transfer problems due to the rapidly changing refining processes and techniques.

This knowledge and experience can be valuable to you when you have a heat transfer problem.

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"Masterflex" Prefabricated Piping Systems • "Masterweld" pressure vessels for Power, Refinery and Chemical Industries. Heat Exchangers. Pyrolytic and Catalytic Cracking Units, Hydroforming, Reforming, Dehydrogenation, Alkylation, Desulphurization. Thermal and Catalytic Polymerization Units • JUIK Processes for Lubricating Oil Plants. Plastic Refractories • Radial Brick Chimneys.

R-S
No. 633
Four to six revolutions of the hand wheel completely open or close the valve vane.
RUGGED
150-Pound Valve
Better Built Than 300-pound Steel Standard

Designed for high temperature gases, heavy chemicals, catalysts and high octane gasoline operations, this R-S 150-pound All-Steel Butterfly Valve, with the exception of the 150-pound raised face flanges, is actually better built than a 300-pound steel standard. Body, vane, shafts, keys, bushings and bearings far exceed 150-pound ASA requirements. Outlasts 150-pound pipe fittings.

No. 626

60-inch valve with finned stuffing box, chain wheel operated.

Equipment consists of a 300-pound hydraulic cylinder with zero to 15 psi positioner, heavy-duty hand wheel, self-locking worm and gear and declutching unit.

A paramount feature of all R-S Butterfly Valves is the fact that the flow "fans out" into a crescent-shaped spray when the vane approaches a closed position. Wear is not confined to one small surface with a consequent weakening of the valve wall when abrasive materials are handled.

Write for details and Catalog No. 14-B.

• 15 to 900 psi •

VALVE DIVISION
R-S PRODUCTS CORPORATION
120 Berkley Street • Philadelphia 44, Penna.

R-S Streamlined BUTTERFLY VALVES

plete line of plastic coaters for melting ethylcellulose and other plastics used in coating parts for protection in shipment.

General Electric Offers Electronic Training Course

General Electric Company, Schenectady 5, New York, has made available a training course which includes 12 practical lessons in industrial electronics. The course offers a practical presentation of industrial electronics, including understandable descriptions and characteristics of the various types of tubes used in industry. The greater part of the course is devoted to specific industrial applications, showing present uses and future possibilities. Phrased in non-technical terms, it is designed to bring practical appreciation of the subject within the range of a wide scope of industrial personnel.

Designed for group study, equipment includes 12 slidefilms and records, together with review booklets keyed to the slidefilms and an instructor's guide. Price of this equipment is $100.

Lunkenheimer Elects

The Lunkenheimer Company, Cincinnati, recently elected the following officers and directors: Frank P. Rhame, president and general manager; Homer E. Lunken, vice president and assistant general manager; Harry A. Burdorf, vice president, sales; Charles W. Burrage, secretary; Chester C. Isekeit, treasurer. Directors are Harry A. Burdorf, Henry G. Frost, Chester C. Isekeit, Carl M. Jacobs, Edmund P. Lunken, Homer E. Lunken, Frank P. Rhame.

George T. Horton Dead

George T. Horton, 71, president of Chicago Bridge & Iron Company, died March 19. He had been associated with the company, founded by his father, Horace E. Horton, since graduation from Rensselaer Polytechnic Institute in 1893, and had been president since his father's death in 1912. He was noted as an engineer, and many of the company's designs were his development. He was an honorary member of the Western Society of Engineers and Chicago Engineers Club, and participated in the activities of American Welding Society, having served as its president. Other engineering affiliations included American Society of Civil Engineers, American Society for Testing Materials, Society of Naval Architects and Marine Engineers, American Petroleum Institute, and Engineers Club of New York. He served as an alumni trustee of Rensselaer from 1925 to 1928, and had been a life trustee since 1929.

Final Contribution Made From War Rubber Drive

Petroleum Industry War Council has given its check for $9,233.63 to United Service Organizations, as the final contribution from proceeds of the rubber drive.

In 1943, PIWC, as trustee, distributed equally to the Army Emergency Relief, Navy Relief Society, American Red Cross and United Service Organizations, $2,433,185.20. This amount represented the excess of receipts from the rubber drive which was conducted by the petroleum industry, June 15 through July 10, 1942.

NEW EQUIPMENT

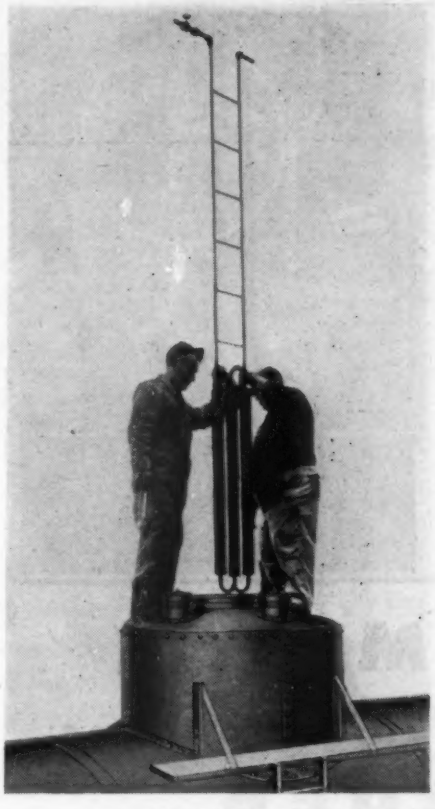
...MANUFACTURERS·LITERATURE...

FOR FREE COPIES OF MANUFACTURERS LITERATURE OR MORE INFORMATION ON PRODUCTS DESCRIBED ON THESE PAGES, USE THE MAILING CARD INSERTED IN THIS ISSUE

1—Steam Tank Heater

The Brown Fintube Company, 160 Filbert Street, Elyria, Ohio, recently has introduced an immersion type steam tank heater for tank cars and tank trucks. The heater consists of a number of lengths of the company's "Fintubes" connected in series, and inlet and outlet steam lines. The heaters have low center of gravity, and can be handled safely by one man, or easily by two men. Cross handles aid in positioning the heater over the discharge outlet in the car, in blocking the heater at various depths, and removing the unit after the car is empty. The heater is available in two sizes, one for railroad cars and the other for tank trucks.

Use of these heaters speed up unloading, and permit many viscous materials being handled in cars not fitted with steam coils.



Brown Fintube Tank Heater

2—Fluorescent Light Unit

Holophane Company, 342 Madison Avenue, New York 17, has announced a new fluorescent lighting unit designed especially for the petroleum and chemical industries. It is vapor tight and of rugged construction to withstand severe operating conditions. The lenses are of glass that will withstand unusual mechanical and thermal shock.

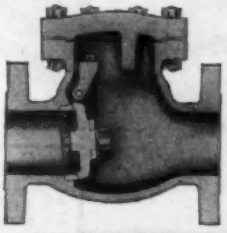
3—Universal Link Joint

Piezoelectric Corporation, 110 East 42nd Street, New York 17, has announced the Piezo Universal Link Joint, a remote control product which features an adjustable link mechanism to transmit rotary motion around corners. It permits operation of shafts at an angle up to 90 degrees. The output shaft turns in the exact angular rotation as the input shaft, which is important in dial settings and where uniform motion is required. This item is recommended by the manufacturer for hand operation, and for slow-speed power drives, such as those used in the control of electrical switchboards, automatic machinery, valve operation and many other mechanical devices.

Piezo Universal Link Joint

4—Check Valves

The Ohio Injector Company, Wadsworth, Ohio, has announced a new line of OIC cast steel swing check valves in the 150- and 300-pound pressure classes. They are the full-way type in which the disc completely clears the waterway in the wide-open position. The complete disc assembly is suspended from brackets inside the body, and is removable as a unit through the cap opening.



OIC Check Valve

5—Diesel Exhaust Monitor

The Ess Instrument Company, Ft. Lee, New Jersey, has announced the "Hazegage," an instrument for evaluation of the exhaust from diesel engines. The instrument consists of a light unit, a photo-electric unit, and an indicator which has a scale and two different colored lights. In operation, the light unit shoots a path of light through the exhaust haze, and the photo-electric unit measures the density of the haze and shows it on the scale of the indicator. When combustion varies so that the haze is either too thick or too thin the condition will be indicated on the scale and signaled by a light. Sound alarms and recorder-equipped models also are available.

6—Vapor-Tight Tank

Hammond Iron Works, Warren, Pennsylvania, has developed a "Vapor-Lift" roof tank designed to stop breathing losses, reduce filling losses and preserve the quality of stored products. The tank provides a variable, positively sealed vapor space of ample capacity.

Chief feature of the tank is a stabilizing apparatus which insures the roof being kept level at all times, regardless of wind or unbalanced snow loads. These stabilizers consist of gear and rack units synchronized by a continuous chain and cable with take-ups. Roller guides mounted on non-corrosive bearings insure true vertical alignment of the roof during its travel. All equipment is located outside the tank where parts are accessible for inspection.

An oil seal and dip ring seal the vapor space. The dip ring, an integral part of the roof, rides in the oil chamber, thus reducing and enlarging the vapor space in the tank. The liquid seal chamber is filled with an oil selected to meet the lowest operating temperature, and seals the dip ring to prevent escape of vapors.

The weather skirt is of reinforced rigid construction to form a canopy

Hammond Vapor-Tight Tank

For the Safety of SHIPS...

America needed ships . . . 50,000,000 tons of cargo, tanker and transport ships, in addition to a vast fleet of Naval vessels—*and all of these ships needed safety valves, relief valves, and pressure gauges!*

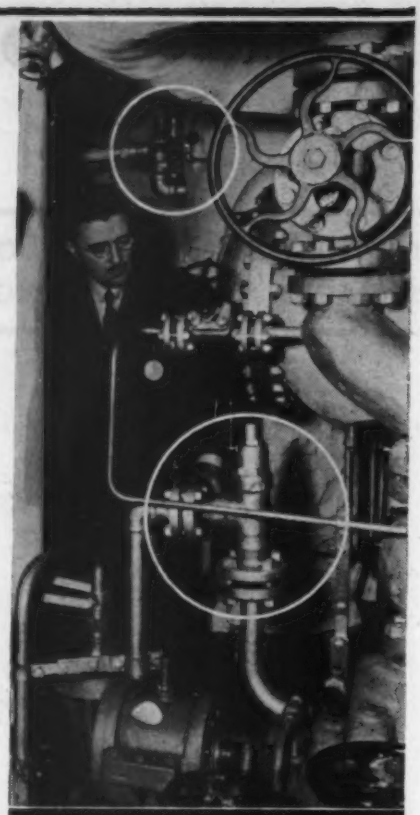
Where did all these valves and gauges come from? Lonergan produced a lot of them . . . thousands of tons of them . . . and did so in addition to serving many of America's other vital war industries.

The facilities and 73 years of "know-how" that made possible this production achievement are at your service whenever you need *Safety Valves, Relief Valves,* or *Pressure Gauges.* Get Lonergan recommendations on your next inquiry.

J. E. LONERGAN COMPANY, 216 N. 2nd St., Phila. 6, Pa.

Lonergan

Safety Valves • Relief Valves • Pressure Gauges
SINCE 1872 — Makers of Pressure-Safety Appliances for the Power, Mechanical, and Process Industries



TWO OF MANY TYPES OF LONERGAN RELIEF VALVES USED ON SHIPS

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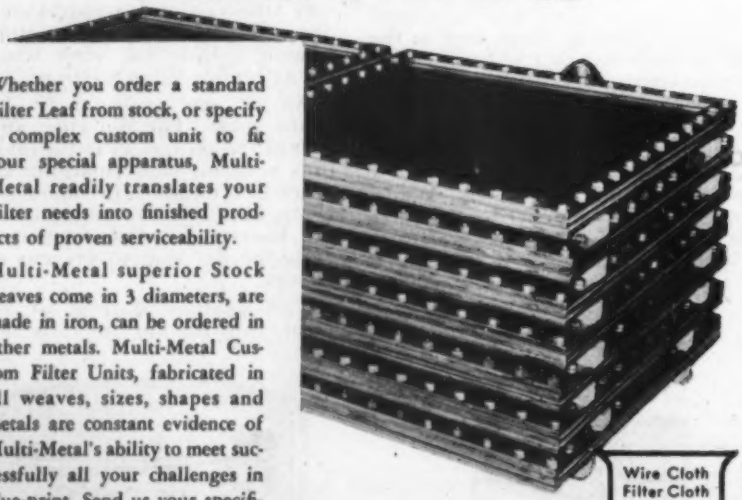
MULTI-METAL

likes its Filter Unit problems

TOUGHER



Whether you order a standard Filter Leaf from stock, or specify a complex custom unit to fit your special apparatus, Multi-Metal readily translates your Filter needs into finished products of proven serviceability.

Multi-Metal superior Stock Leaves come in 3 diameters, are made in iron, can be ordered in other metals. Multi-Metal Custom Filter Units, fabricated in all weaves, sizes, shapes and metals are constant evidence of Multi-Metal's ability to meet successfully all your challenges in blue-print. Send us your specifications and ask about our helpful catalog.

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Wire Cloth in Fabricated Units or by the roll and the cut piece

Wire Cloth
Filter Cloth
All Meshes
All Metals

Multi-Metal
WIRE CLOTH COMPANY, INC.
1350 Garrison Ave., New York 59, N. Y.

For copies of manufacturer's literature or additional information on products described, use the mailing card inserted at page 249 of this issue. Numbers on card correspond to descriptive paragraphs.

which protects the liquid seal and the stabilizer against the elements.

The outer rim of the roof incorporates a heavy circular girder that maintains the shape of the roof, constant under all working conditions and insures trouble-free operation unaffected by wind, snow, ice or rain.

A drip ring attached to the under side of the roof just inside the tank shell serves as a barrier to prevent vapors which condense on the under side of the roof plates from getting into the liquid seal.

Under normal conditions the roof rests on the roof supports as in the conventional cone-roof tank. As the volume of vapor in the tank tends to increase, the roof rises to make room for the increased vapor, lowering itself when the volume of vapor increases. A single installation can be provided with vapor capacity to accommodate the breathing of additional tanks. The tanks are available in sizes up to 100,000 barrels capacity.

7—Car Puller

American Engineering Company, Philadelphia 25, Pennsylvania, has introduced a Class 2½ Lo-Hed car puller. The puller is a husky hauling device in which the barrel, gear box and motor are integrated in a single, streamlined unit.

Starting line pull is 5000 pounds using a single line, or more with various block combinations. In addition to moving cars, a special application of the device to the oil industry is that of bending pipe, and it has many other fields of usefulness, wherever a hauling problem presents itself.

8—Fire Hose

Goodyear Tire & Rubber Company, Akron, Ohio, has announced a fire hose fabricated with synthetic rubber and especially suited for use where the hose comes in contact with oils and acids. The new hose, designated as Type M, differs from the conventional in that the cotton fabric which ordinarily is the outside sheath of fire hose, is between an outside and inside layer of synthetic rubber—composition of the inside being resistant to deterioration from special fire-fighting compounds. The hose is being produced in 1½-, 2-, 2½- and 3-inch diameters.

9—Stabilized Alloy

Lebanon Steel Foundry, Lebanon, Pennsylvania, is distributing a bulletin on Lebanon Circle L 21, a columbium-stabilized alloy for corrosion-resistant weldments.

10—Electronic Thermometer

Bailey Meter Company, 1050 Ivanhoe Road, Cleveland 10, Ohio, has published Bulletin No. 230-A, which features Bailey Pyrotron electronic thermometers in indicating, recording and controlling models, for temperature ranges between—100°F. and 1200°F. This 12-page bulletin describes the electronic detector and motor control, and gives infor-

an Old Product

TAKES ON NEW TASKS

Plain, old-fashioned Bicarbonate of Soda is an amazingly versatile chemical product. Household remedy for many common ills . . . key ingredient for dozens of pharmaceuticals . . . basic in baking powder and millers' choice for self-rising flour—"bi-carb" plays its homely, useful roles.

"Bi-carb" is just as essential in hundreds of industrial operations . . . is the active ingredient in several types of fire fighting equipment . . . helps tan leather . . . prevents sap stain in lumber . . . performs importantly in the production of plastics, sponge rubber and in heat-treatment of special steels . . . neutralizes acids and removes caustic.

Through Mathieson Research, "bi-carb" assumes great new importance in the textile industry. Commercially developed, Mathieson's new process for removing caustic with "bi-carb" speeds up production, lowers cost, eliminates acid's disadvantages . . . removes caustic by *changing* it into sodium carbonate (soda ash).

The Mathieson Research and Technical Staffs are also applying "bi-carb" experience to certain phases of the paper industry. Perhaps their accumulated knowledge of "bi-carb's" versatility may hold important meaning for you—may bring to light possibilities you haven't thought of. *Cooperation means progress for all.*

Mathieson
CHEMICALS

THE MATHIESON ALKALI WORKS (INC.) 60 EAST 42nd ST., NEW YORK 17, N. Y.

BICARBONATE OF SODA . . . CAUSTIC SODA . . . SODA ASH . . . LIQUID CHLORINE . . . CHLORINE DIOXIDE
AMMONIA, ANHYDROUS & AQUA . . . . H T H PRODUCTS . . . . FUSED ALKALI PRODUCTS . . . . SYNTHETIC SALT CAKE . . . . DRY ICE . . . . CARBONIC GAS . . . . SODIUM CHLORITE PRODUCTS . . . . SODIUM METHYLATE

Kel-Bloc does a better insulating job than TWO BLOCKS formerly did

This economical, high temperature and moisture-resistant insulation block covers the entire temperature range up to 1600°F— eliminating the former method of using two blocks; one for low and one for high temperature.

Made under carefully controlled conditions the long-fibre black Rockwool is fitted and bonded together to give uniform density, and, due to special method of fitting, all voids are eliminated and stratification is uniform.

Because of the care of manufacture, Kel-Bloc forms a strong resistant insulation which absorbs expansion stresses. Recommended particularly for insulating pressure vessels, heat exchangers, steam accumulators, boilers, furnaces, oil heaters, dryers, ovens, breechings, ducts, etc.

One block does double duty— keeps heat in, cold out!

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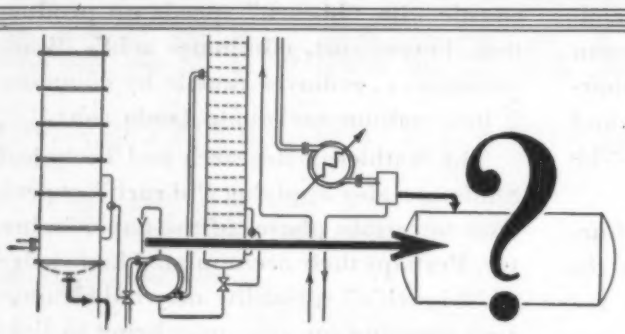
THE M. W. KELLOGG COMPANY

Sales Office: 225 Broadway, New York 7, N. Y. Plant: Jersey City, N. J.

Representatives in CHICAGO • DETROIT • PITTSBURGH • LOS ANGELES



If you know what you want as an end-product, or what you can start with, Hicks engineers can solve your process and/or equipment problems.

By-products
New processes
Yield increases
Improved products
Syntheses
Recovery

may be possible in your process work.

Investigate and *engineer now* — build now or later.

Here as in China, "To go anywhere, you must take the first step." Write

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51 EAST 42ND ST., NEW YORK 17, N. Y.

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mation on ranges, power supply required, speed of response, accuracy, sensitivity, installation, standard chart ranges, automatic-control application, alarm contacts, temperature-sensitive elements, and measuring circuits.

11—Full View Fittings

Henry E. Jacoby, 205 East 42nd Street, New York 17, has an eight-page illustrated bulletin descriptive of a line of "full view" fittings for installation in pipe lines and on process equipment as a means of readily determining the general condition and flow of liquids in process.

12—Protective Coatings

Carbozite Corporation, First National Bank Building, Pittsburgh 22, has issued a new booklet giving instructions for applying protective coatings. It also lists and describes the several products of the company.

13—Electronics

General Electric Company, Schenectady 5, New York, has issued a folder, GES 3303, in which announcement is made of availability of material for a training course in industrial electronics.

14—Alkali and Acid-Resistant Cement

The U. S. Stoneware Company, Akron, Ohio, is distributing its Bulletin R-5, "Duracite Alkali- and Acid-Resistant Cement." The product described is a furane-base resin cement, resistant to most inorganic acids, organic acids, alkalies of any degree of concentration, oils, and solvents.

15—Centrifugal Pumps

Marlow Pumps, Ridgewood, New Jersey, is distributing "Self-Priming Centrifugal Pumps," by A. S. Marlow, Jr. In "first-reader" style it sets forth the principles of centrifugal action, the physics of pumping and the evolution of self-priming centrifugal pumps.

16—Wax

Glyco Products Company, 26 Court Street, Brooklyn 2, New York, has published a 16-page bulletin entitled "A High-Melting-Point Synthetic Wax," which gives detailed information on "Acrawax C" produced by the company.

17—Controls

B/W Controller Corporation, 2200 East Maple Road, Birmingham, Michigan, has issued its Catalog No. 145, on floatless liquid-level and industrial controls. The illustrated booklet includes application diagrams and other engineering data.

18—Labor Relations

Allis-Chalmers Manufacturing Company, Milwaukee 1, Wisconsin, has offered as a public service to send to individuals or groups interested in the problem of rehabilitation of returning war veterans copies of a manual prepared for its own supervisory force. "Because we wished to have this manual as complete and psychologically sound as

KILL TOUGH FIRES BEFORE THEY GROW—WITH KIDDE EQUIPMENT

WHEN tough fires spring up—the fast-moving ones that break out in flammable liquids (Class B); the hard-to-get-at kind that start in electrical equipment (Class C)—the Kidde portable or hose reel system acts fast to knock them down—and *out!*

Ordinary water-type extinguishers can't control these tough fires. But the Kidde portable shoots out a cloud of carbon dioxide gas, forming a heavy blanket that smothers the flames. Then the dry, inert, non-toxic gas merely evaporates...leaving petroleum products *uncontaminated*, electrical equipment *undamaged*. This Kidde method is recognized as one of the speediest, cleanest and safest fire-fighters in use today.

It's smart to check on tough fire areas in your own business. Does the accompanying list of typical hazards suggest places that still need safeguarding? If it does, call in a Kidde representative—you'll find him wise when it comes to fire protection. Drop us a line.

Kidde Kills Tough Fires

- STORAGE ROOMS
- PUMP ROOMS
- TANK TRUCKS
- ELECTRICAL EQUIPMENT
- PAINT STORAGE
- ANTIFREEZE ROOMS
- PIPE LINE PUMPING STATIONS
- CASE AND CAN ROOMS
- CONTROL ROOMS
- LABORATORIES
- BULK PLANTS

The word "Kidde" and the Kidde seal are trade marks of Walter Kidde & Company, Inc.

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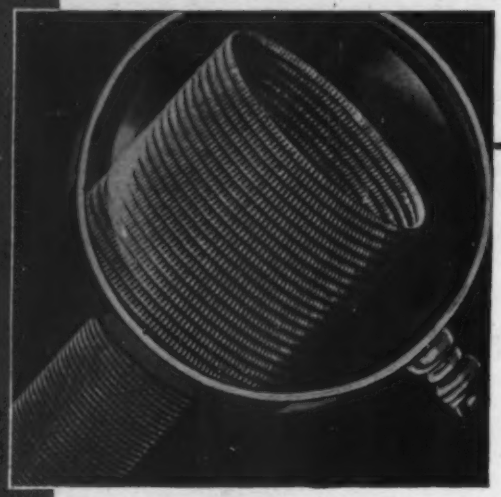
PREVENT

Rust · Scale · Dirt

FROM CLOGGING
STEAM EQUIPMENT



YARWAY

STRAINERS

"The Screen's the Thing"

- *A High Grade Monel Woven Wire Basket* with mesh fine enough to catch the dirt—yet ample free area for passage of clean condensate, oil and other fluids.
- *Body Cadmium Plated Inside and Out for Protection Against Corrosion.*
- *Readily Removed Steel Blow-Off Bushing.*
- *Bushing Automatically Aligns Screen.*
- *Thousands in Use—Sold by Over 100 Mill Supply Houses.*
- *6 Sizes ½" to 2" for Pressures up to 600 Lbs.*

See Your Supply House or write for Bulletin S-200

YARNALL-WARING COMPANY

128 MERMAID AVENUE PHILADELPHIA 18, PA.

YARWAY STRAINERS

For copies of manufacturer's literature or additional information on products described, use the mailing card inserted at page 249 of this issue. Numbers on card correspond to descriptive paragraphs.

possible," says a company spokesman, "we enlisted the assistance of the Wisconsin Society for Mental Hygiene. This assistance, plus our own experience in already employing more than 1,100 veterans of this war, we feel, makes this manual a unique contribution to the veterans' rehabilitation program."

19—Universal Link Joint

Piezoelectric Corporation, 110 East 42nd Street, New York 17, is distributing Bulletin No. 45, descriptive of its Universal Link Joint for manipulation of instruments and valves by remote control at an angle.

20—Tube Cleaning

Thomas C. Wilson, Inc., 21-11 44th Avenue, Long Island City 1, New York, is distributing Bulletin No. 75, which is a step-by-step check list of steps to be taken before, during and after a tube-cleaning operation. It covers selection of equipment, cleaning procedure, care of cleaning equipment, and types and sizes required. Illustrations identify equipment described and recommended.

21—Burners

Peabody Engineering Corporation, 580 Fifth Avenue, New York 19, is distributing a new bulletin, No. 902, describing the Peabody Type M gas burner and the combined gas and oil burner. It describes and illustrates the mechanical and operating features of these burners, for natural or forced-draft operation, and shows the types of atomizers used for oil firing.

22—Gas-Engine-Driven Compressors

Ingersoll-Rand Company, 11 Broadway, New York 4, has announced availability of Form 3081, a catalog describing KVG four-cycle V-angle type gas-engine-driven compressors. A complete and instructive book, it lists the basic features of the KVG, shown to be available in five models, from 600 to 1000 horsepower. Also shown is a companion engine model, PKVG, in sizes 600 to 1200 horsepower.

23—Steel Grating

Water Bates Company, 1707 Rowell Avenue, Joliet, Illinois, has issued a catalog on open steel flooring and stair treads which suggests ideas for design and construction. Charts show safe loads for open steel flooring.

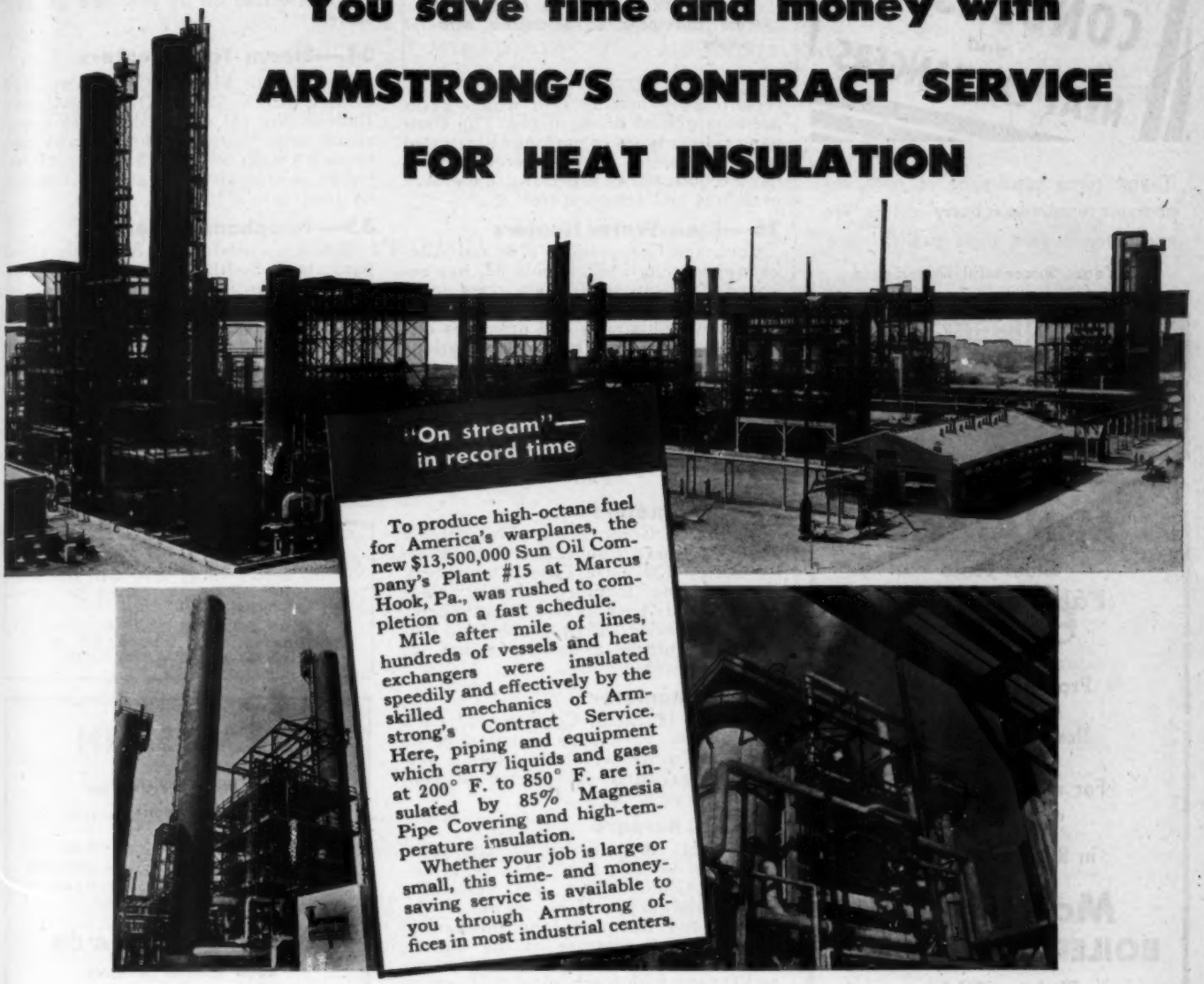
24—Deep-Well Pumps

Byron Jackson Company, Pump Division, Box 2017 Terminal Annex, Los Angeles 54, has issued Bulletin 44-5000, which describes and illustrates development of its deep-well pumps for water supply.

25—Metallic Packing

C. Lee Cook Manufacturing Company, Louivsille 3, Kentucky, is distributing its Catalog No. 440—"Cook's Metallic Packings for Piston Rods of All Engines and Compressors." This is a handsomely printed engineering treatise on the problems of packing pistons of

You save time and money with
ARMSTRONG'S CONTRACT SERVICE
FOR HEAT INSULATION



"On stream"— in record time

To produce high-octane fuel for America's warplanes, the new $13,500,000 Sun Oil Company's Plant #15 at Marcus Hook, Pa., was rushed to completion on a fast schedule.

Mile after mile of lines, hundreds of vessels and heat exchangers were insulated speedily and effectively by the skilled mechanics of Armstrong's Contract Service. Here, piping and equipment which carry liquids and gases at 200° F. to 850° F. are insulated by 85% Magnesia Pipe Covering and high-temperature insulation.

Whether your job is large or small, this time- and money-saving service is available to you through Armstrong offices in most industrial centers.

YEARS OF EXPERIENCE in engineering both large and small jobs is an advantage that pays you dividends when you use Armstrong's heat insulation contract service. It assures planning and supervision that speed work and keep costs low. In addition, Armstrong's complete service provides materials of tested efficiency; also skilled, experienced mechanics for installation. Armstrong takes full responsibility for every phase of the work. For detailed information, write to Armstrong Cork Company, Building Materials Division, 7504 Concord Street, Lancaster, Pennsylvania.

ARMSTRONG CORK COMPANY

Complete Insulation Contract Service for
All temperatures from 300° below zero to 2600°F.

QUICK REPAIRS ON
CONDENSERS
and
HEAT EXCHANGERS

If you need condenser or heat exchanger repairs **in a hurry** call us. We specialize in fast, high quality work.

25 Years Successful Experience

GULF ENGINEERING CO., INC.
"Service Not Promises"
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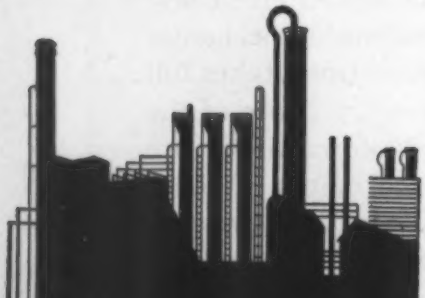

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For copies of manufacturer's literature or additional information on products described, use the mailing card inserted at page 249 of this issue. Numbers on card correspond to descriptive paragraphs.

reciprocating machines in which gases are compressed or expanded. The company claims types of packings illustrated will take care of over 95 percent of today's requirements, especially in elevated pressures and temperatures.

26—Feed-Water Heaters

Cochrane Corporation, 17th and Allegheny Avenue, Philadelphia 32, has released Publication 4091, on open feedwater heaters of various types. This publication illustrates and describes different types of tray heaters for various applications, the jet heater, V-notch metering heater, and the convertible tray type of heater which by insertion of additional trays can be converted into a deaerator. Illustrations show various combinations of heaters with storage tanks.

27—Rotameters

Cochrane Corporation, Philadelphia 32, has released Publication R-100A, on its Series 100 Case-Type Rotameters. Data presented includes "what is a rotameter?" and "how to select a rotameter for your service." Photographs and diagrams illuminate a handsome and instructive booklet.

28—Tachometer

Herman H. Sticht Company, 27 Park Place, New York 7, is distributing its Bulletin No. 760 which describes a new triple-range hand tachometer of centrifugal type.

29—Oil Burners

Peabody Engineering Corporation, 580 Fifth Avenue, New York 19, is distributing Bulletin No. 802, describing the Peabody Type M oil burner. It describes and illustrates the mechanical and operating features of the burner, for natural or forced draft operation, and for use with mechanical, wide-range mechanical or steam atomizers.

30—Safety Clothing

American Optical Company, Southbridge, Massachusetts, has announced a new bulletin which lists and describes safety clothing for male welders.

31—Centrifugal Separators

Merco Centrifugal Company, Hobart Building, San Francisco 4, has issued Bulletin No. 501, describing "The Separation of Suspended Solids," and the application of Merco centrifugals.

32—Centrifuges

The Sharples Corporation, 2300 Westmoreland Street, Philadelphia 40, has the following three bulletins available:

Bulletin 1226-C, a technical presentation of centrifugal force by Arthur Ayres, the company's chief engineer. In addition to theoretical discussion, it includes data on design, installation and operation.

Bulletin 1230-B, "How the Bowls of Sharples Super-Centrifuge Function," graphically shows how centrifugal force effects separation of heavy and solid liquids.

Bulletin 1234-B describes equipment especially designed for clarification of paints and lacquers.

33—Steel Valves

Sollberger Engineering Company, Marshall, Texas, is distributing a four-page bulletin which gives engineering details on construction of its new line of steel valves.

34—Steam Tank Heaters

The Brown Fintube Company, 160 Filbert Street, Elyria, Ohio, has issued Bulletin No. 451, which describes a new steam tank heater for use in tank cars or tank trucks to speed handling of materials whose viscosity can be lowered by heating.

35—Telephone Systems

Kellogg Switchboard & Supply Company, 6650 South Cicero Avenue, Chicago 38, has issued Form 766, which gives illustrated data on its private automatic exchange telephone systems.

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